Planning for Blue and Green: A Case for Green Infrastructure

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1.0 Abstract

With the growing and ever present need to address the impacts of climate change, the burdens placed on cities' stormwater management systems are exceeding the capacity. In recent years, green infrastructure has been one of many highly discussed strategies that may better address these conflicts, but it is not a new invention. Concepts of green infrastructure can be traced back to germ theory and Fredrick Olmstead's parks to landscape urbanism and Design with Nature. Today, the idea of green infrastructure surpasses theory and naturalistic design. It is merged with policy, economic development, stormwater management, and street infrastructure to become a part of a multitude of cities landscapes around the globe. Prior to implementing green infrastructure, we need to understand what green infrastructure is; its capabilities, gaps and conflicts; potential impacts; and an understanding of the needed investments to make green infrastructure feasible and maintainable. Analyzing the planning process and the implementation strategies other cities have taken will result in a better understanding of how to implement infrastructure appropriately and better consider the circumstances of the urban landscape.

With a knowledge of successes and failures in implemented green infrastructure, we can use that information to propose best management practices for the City of Atlanta that are considerate of the social, economic, and environmental factors of the city. It is our hope that as green infrastructure becomes more common that cities make more informed decisions that are embracive the existing fabric of the city and enhance it.

2.0 Introduction

Green infrastructure has been highly discussed in recent years, but it is not newly discovered. Concepts of green infrastructure can be traced back to germ theory and Fredrick Olmstead's parks to landscape urbanism and *Design with Nature*. Today, the idea of green infrastructure surpasses theory and naturalistic design. It is merged with policy, economic development, stormwater management, and street infrastructure to become a part of a multitude of cities landscapes. Cities with problems with stormwater management are seeking opportunities to improve their infrastructure systems that are both cost effective, smart, and multifunctional. Green infrastructure is being considered as a potential tool. Before analyzing how green infrastructure can being implemented, we need to understand what green infrastructure is; its capabilities, gaps and conflicts; potential impacts; and an understanding of the needed investments to make green infrastructure feasible and maintainable. The following section will dive into how research and practice have begun to answer these questions. It will also highlight, the challenges that have become apparent in this discovery.

3.0 Literature Review

3.1 What is Green Infrastructure?

Green infrastructure is implemented according to the definition the designated bodies decide to use. In order to understand why it is used, we need to understand the varying definitions. While the federal government is not the actual body implementing green infrastructure, its endorsement has proven valuable. The Environmental Protection Agency works as the department to oversee projects that include green infrastructure in stormwater infrastructure improvements that are monitored at the state and federal levels. The EPA

defines green infrastructure as a cost-effective, resilient approach to managing wet weather impacts like reducing and treating stormwater at its source while delivering environmental, social, and economic benefits [1]. While highlighting the multifunctional benefits, the Environmental Protection Agency's definition prioritizes the benefits of integrating green infrastructure for stormwater management over other benefits.

One of the other perspectives prioritizes the socio-ecological point of view. By creatively combining natural processes and technology in green infrastructure, we can intentionally achieve resiliency goals for society and the environment [2]. These concepts are similarly found within the theory of landscape urbanism. Landscape urbanism critiqued the ideas that architecture, urban design, and planning were able to create competent explanations of urban conditions. The theory of landscape urbanism is to take the approach of looking at ecological and infrastructure systems thus shaping social, political, and the economic environment. With this structure, landscape urbanism was designed as a framework and tool "capable of temporal change, transformation, adaptation and succession"[3]**.** While these concepts are ideally comprehensive in their approach and implementation, the founding fathers of this theory -Ian McHarg and Koolhaas/OMA - are trained landscape architects. Critiques of landscape urbanists highlighted that the application of this theory was implemented with a one-sided approach. Landscape urbanist projects materialized around hydrology and the basis of design and federal

[1] "What Is Green Infrastructure?" EPA, Environmental Protection Agency, 3 July 2018, www.epa.gov/green-infrastructure/what-green-infrastructure.
[2] Staddon, C., Ward, S., Vito, L., Zuniga-Teran, A., Gerlak, A., Schoeman, K., . . . Booth, A. (2018). Contributions of green infrastructure to enhancing urban resilience. Environment Systems and Decisions, 38(3), 330-338.
[3] Charles Waldheim, (1997/2006) "Landscape as Urbanism," The Landscape Urbanism Reader (C).

measures as a technical metric thus lacking the social perspective [4]. This was contradictory because the designers were not engineers but were focused on the technical aspects of the design rather the that social or the environmental.

The technical perspective of green infrastructure prioritizes the engineering factors and outcomes over the environment and the society. Factors such as stormwater runoff volumes, peak flows, and pollutant loads are analyzed to understand the processes of infiltration, evapotranspiration, and capture rates to reduce the amount of stormwater runoff volume [5]. This definition further acknowledges the contributions to the environment and the community, but the primary focus is in the function of the infrastructure assets.

While the definitions of green infrastructure have commonalities, the implementation of the infrastructure greatly impacts the outcome. Green infrastructure is designed around several factors- function, benefit and need- however the scale of implementation greatly influences. This scale of green infrastructure determines the use and the governing structure over the project which creates diversity and variety within the sector. [6] Community scale green infrastructure allows for greater community participation and engagement. This scale often comes in the form of rain gardens and community gardens. At this scale the community has greater input on the programmatic function and the needs as the people who will benefit from the project are directly involved. This scale of project may be planned directly with local government or is may be through a not-for-profit organization or the community itself with

[4] Duany, Andres and Talen, Emily, (2013) "Looking Backward: Notes on a Cultural Episode" from Landscape Urbanism and its Discontents: Dissimulating the Sustainable City(Gabriola Island: New Society Publishers, 2013)
[5] Greeley and Hansen. "CSS Long Term Control Plan Update Green Infrastructure Strategy." City of Alexandria, City of Alexandria, VA Department of Transportation and Environmental Services, June 2016, www.alexandriava.gov/uploadedFiles/tes/oeq/info/GI%20Strategy-FINAL.pdf.
[6] Jerome, G. (2017). Defining community-scale green infrastructure. Landscape Research, 42(2), 223-229.

little assistance. This factors in directly to the level financial investment in the project. With minimal investment in a small scale project, the needs and priorities are prioritized to be social motivated.

As the scale of green infrastructure increases to large projects, the priorities of business and economics become more prevalent. This is justified as these projects often require significant capital investment. [7] While the public government is providing a service for the public good, precedent has shown that the potential return on investment is great for example in Ponce City Market and the Highline which have become world renowned green infrastructure projects. This "business case for green planning" can diminish the social priorities particularly of the surrounding residents simply because the idea of the "community" is enlarged past the bordering neighborhoods. Large scale green infrastructure often materializes in the form of traditional parks, stormwater parks, trails, and greenways. These types of public amenities may be viewed as economic generators, but they were originally advocated for as the "lungs of the city" by the sanitary and health reformers in the 1850s.[8] During that time, the city during the industrial area was being burdened by urban growth, poor living conditions, diminishing air quality, contaminated drinking water, diseases, poor infrastructure, congestion as well as other challenges. To remedy the mental effects of these challenges for the residents, Olmstead advocated for incorporating nature into the city.

Green infrastructure for stormwater management is often implemented at the city scale. While the community may have a say in the design standards, the governance of the project is

[7] Jerome, G. (2017). Defining community-scale green infrastructure. Landscape Research, 42(2), 223-229.
[8] Eisenman, T. (2013). Frederick Law Olmsted, Green Infrastructure, and the Evolving City. Journal of Planning History, 12(4), 287-311.

predominantly the local government, specifically the department of public works. This department specifically takes on the administration role because areas of administration are in the public right of way. Green infrastructure that is integrated into the streetscape is also able to be stitched into the stormwater management plan when planned accordingly.[9] Projects of this type consist of street trees, median plantings, bioswales, rainwater gardens and impervious surfaces.

3.2 The Effectiveness of Green Infrastructure:

Green infrastructure in theory and application has been proven to be effective in a variety of ways. Green infrastructure contributes to resiliency and climate change mitigation goals. Based on the definition defined by *100 Resilient Cities*, resiliency is the "capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience ".[10] Green infrastructure contributes to this by replacing and restoring previously destroyed natural ecosystems. It has the capability to produce local ecosystem services, such as air purification, rainwater drainage, sewage treatment and food provision, alongside recreational and social benefits.[11] These benefits promote resiliency efforts with low impact development and natural processes. Nevertheless, the likelihood of obtaining these benefits is dependent on the initial considerations and application of the infrastructure.

[9] Eisenman, T. (2013). Frederick Law Olmsted, Green Infrastructure, and the Evolving City. Journal of Planning History, 12(4), 287-311.
[10] "What Is Urban Resilience?" 100 Resilient Cities, 2019 100 Resilient Cities, 100resilientcities.org/resources/#section-1.
[11] Schäffler, & Swilling. (2013). Valuing green infrastructure in an urban environment under pressure — The Johannesburg case. *Ecological Economics, 86*, 246-257.

Adaptation within the existing conditions of the urban environment requires sustainable development. In dense urban environments, access to previously undeveloped public land is rare and complex. While it may be available, it may be designated for a preexisting purpose. In addition, taking private land for the purpose of public infrastructure is a lengthy legal process and can be highly scrutinized. For these reasons, green infrastructure is an optimal solution, but varies in scale. In particular, small scale infrastructure is low impact and cost efficient. One of the techniques is to use rain gardens as a low impact development strategy to mitigate the impacts of urban development. Its size retains a defined and measurable volume to act as a retention system.[12] These systems have been used for public works as well and private owns to mitigate the impact of flooding on site. Nevertheless, these assets are site specific and designed for potential flows. Serving as a subset of greenspace planning, green infrastructure works to create and manage networks of green space in urban environments. This planning approach is commonly supported by policy to preserve and restore ecological networks while creating social and recreation spaces for the public.[13] This multifunctionality specifically supports sustainable development in urban environments where open space and land are valuable amenities.

Even within green space planning, planning for water is either required or added in order to solve stormwater complications. As urban areas continue to grow in population, development is inevitable. This development results in an increased amount of stormwater to be managed by

[12] Jia, Tang, Luo, Li, & Zhou. (2016). Small scale green infrastructure design to meet different urban hydrological criteria. *Journal of Environmental Management, 171*, 92-100.
[13] Davies, C., & Lafortezza, R. (2017). Urban green infrastructure in Europe: Is greenspace planning and policy compliant? Land Use Policy, 69, 93-101.

a diminishing amount of pervious surface. The reality is that the remaining impervious surfaces cannot efficiently manage the stormwater efficiently. Thus, requiring the water management system to manage an increased amount of stormwater while managing increased amounts of waste water from the increasing population. When planned and engineered intentionally, green infrastructure reduces flood risk and water pollution while easing the burden on the existing water management systems.[14] By mimicking natural hydrology processes, it diverts water from grey infrastructure facilities that traditionally deposit treated water into natural water bodies. Unfortunately, this tactic contributes to erosion and increases the amounts of sedimentation and chemicals in natural water bodies with excess in volumes of water.

While green infrastructure is effective when implemented, the benefits increase with the cost. Green infrastructure has been argued to reduce the cost of water management systems.[15] Instead of transporting water to grey infrastructure it treats the stormwater on-site. It is argued that upgrades to grey infrastructure are costlier and less flexible than green infrastructure even if it is only implemented in the public right of way. In a study conducted by Grand Valley State University on green infrastructure in Grand Rapids, Michigan, they conducted a benefit-cost analysis on six types of green infrastructure. While not all strategies were best suited for the region in all simulations, they had significant positive effects when considering the lifetime benefits and cost.[16] The study acknowledges that the outcomes are region specific and the

[14] Nordman, Erik E., Isely, Elaine, Isely, Paul, & Denning, Rod. (2018). Benefit-cost analysis of stormwater green infrastructure practices for Grand Rapids, Michigan, USA. Journal of Cleaner Production, 200, 501-510.
[15] Grumbles, Benjamin H. Memorandum: Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and Other Water Programs. United States Environmental Protection Agency, Mar. 2007.
[16] Nordman, Erik E., Isely, Elaine, Isely, Paul, & Denning, Rod. (2018). Benefit-cost analysis of stormwater green infrastructure practices for Grand Rapids, Michigan, USA. Journal of Cleaner Production, 200, 501-510.

outcomes may not be replicated because the success of green infrastructure is specific to the implemented region. Nevertheless, there is an array of options. Green infrastructure can range in size and cost. From increasing the plantings of street trees to building a stormwater park, projects can range from several hundreds of dollars to hundreds of millions. Even if a city was financially capable to invest millions of dollars for the purpose of green infrastructure, there are dozens of low-impact and low-cost implementation strategies a city can take to accomplish similar goals.[17]

3.3 Potential Impacts

Theories supporting green infrastructure highlight numerous benefits to its use, but research and actual implementation emphasize that these benefits are most present for the social and environmental. Large scale applications of green infrastructure are developed commonly as open and park space for citizens. Access to and the use of open space has been studied within the field of public health as well as in urban planning. Within the field of public health, it has been emphasized that greener environments and physical activity are highly correlated.[18] These findings are predominantly the results of research focused on the obesity epidemic. Across a portfolio of research, it has been found that proximity to green space is likely to decrease the amount of self-reporting of one being overweight or obese.[19] While these findings are prominent, it is critical to the success of improving health that greenspace be

[17] Staddon, C., Ward, S., Vito, L., Zuniga-Teran, A., Gerlak, A., Schoeman, K., . . . Booth, A. (2018). Contributions of green infrastructure to enhancing urban resilience. Environment Systems and Decisions, 38(3), 330-338.
[18] Coutts, C., & Hahn, M. (2015). Green Infrastructure, Ecosystem Services, and Human Health. International Journal of Environmental Research and Public Health, 12(8), 9768-9798.
[19] Ellaway, A., Macintyre, S., & Bonnefoy, X. (2005). Graffiti, greenery, and obesity in adults: Secondary analysis of European cross sectional survey. BMJ, 331(7517), 611-612.

accessible and distributed across a region. Research has also looked at safety implications of green infrastructure. Philadelphia was one of the first cities to draft and implement green infrastructure into its planning strategy to help solve its stormwater management problems. This strategy used green infrastructure for public right of way improvements as well as large installations like bioswales and basins across the city in areas with combined sewers. The study looked at a four-year period to analyze the impacts of green infrastructure on safety. It found that green infrastructure applications were a deterrent to possession and manufacturing of illegal drugs in public spaces.[20] These co-benefits address health crisis and improve community safety which should be continued to be studied in the future and over longer periods to identify critical factors to understanding how to repeat these successes.

In the field of planning, access to parks space is one of many factors tied to improving the quality of life.[21] Investments in park space that are integrated with green infrastructure and stormwater management also open opportunities to repurpose undevelopable land in to recreational space, restore connectivity between neighborhoods, and bring economic opportunities to a community. The potential social and economic benefits are not only for the immediate community, but for the city. Continued growth, both socially and economically, in underinvested communities, helps with existing initiatives to create healthier communities, funds social programs, and public facilities while increasing the tax base which provides opportunities for the city to continue investment for various projects.

[20] Kondo, Michelle C., Low, Sarah C., Henning, Jason, & Branas, Charles C. (2015). The impact of green stormwater infrastructure installation on surrounding health and safety. The American Journal of Public Health, 105(3), E114.
[21] Dhakal, & Chevalier. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management, 203(Pt 1), 171-181.

While the application of green infrastructure is primarily for environmental purposes, research has been sparse. In a press release, researchers highlighted that the benefits of green infrastructure "on the myriad ecosystem services essential to health has therefore often been underrepresented".[22] This statement is due to the scope of past research that has been conducted as well as the capabilities of the research. Without adequate data or measurements, it is difficult to determine findings to be significant as well as unbiased. It is important to note that green infrastructure application is still relatively young. Cities with early adoption of green infrastructure did not begin implementation till the early 2000s.[23] Lastly, the variety of green infrastructure options and the environmental conditions of a region make it a challenge to assume replication of results in another region. These circumstances make it difficult to generalize the environmental results of green infrastructure. The research conducted by Southern Illinois University looked at the administration of green infrastructure on a case by case basis. Research acknowledges that traditional grey infrastructure is unsustainable as it assists in destroying natural biodiversity and hydraulic processes by removing vegetation and topsoil. [24] With the application of green infrastructure that utilizes local native species, it can assist in bringing back biodiversity, increase the quality of the soil, and decrease erosion speeds. Nevertheless, the use of different plant materials and species may have an effect on the results.

The planning of green infrastructure sits in the category of watershed planning. Watershed planning can be described as "the process of managing human activities and natural resources

[22] New Environmental Research and Public Health Findings from Center for Disease Control and Prevention Outlined (Green Infrastructure, Ecosystem Services, and Human Health). (2015). Health & Medicine Week, 2142.
[23] Kondo, Michelle C., Low, Sarah C., Henning, Jason, & Branas, Charles C. (2015). The impact of green stormwater infrastructure installation on surrounding health and safety. The American Journal of Public Health, 105(3), E114.
[24] Dhakal, & Chevalier. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management, 203(Pt 1), 171-181.

in and area defined by watershed boundaries to protect natural resources for this and future generations".[25] As green infrastructure continues to be a more researched and recognized tool, understanding the impacts of water is critical. A study conducted by Princeton and University of Virginia analyzed to the impacts of green infrastructure on hydrology, water quality, and combined sewer overflows in Baltimore County and Washington DC. The study found that the presence of green infrastructure resulted in a decrease in the magnitude, frequency, duration, and the variability or flashiness of stormwater events when comparing watersheds without green infrastructure.[26] Water quality in these watersheds also had decreased levels of nitrogen and other pollutants. While these results are promising, this study was a case study with only two cities and the results cannot be determined as significant or representative of all stormwater green infrastructure programs.

3.4 Gaps and Conflicts

While there are benefits to the implementation of green infrastructure, it is not immune from failures. Green infrastructure continues to be a broad topic and field of study. Dependent on the approach and the definition will determine the outcome of the implementation. As an arm of sustainability planning, some critique principles of sustainability as privileging the wealthy, but principles they are expected of all.[27] A case study analysis of the approach for the Hawaii 2040 Sustainability Plan found that when we use the triple-bottom-line approach

[25] Durley, J. L. (2007). Linking integrated community sustainability planning and watershed planning in Ontario, Canada. Environments, 35(1), 57-77.
[26] Pennino, Mcdonald, & Jaffe. (2016). Watershed-scale impacts of stormwater green infrastructure on hydrology, nutrient fluxes, and combined sewer overflows in the mid-Atlantic region. Science of the Total Environment, 565, 1044-1053.
[27] Coffman, M., & Umemoto, K. (2010). The triple-bottom-line: Framing of trade-offs in sustainability planning practice. Environment, Development and Sustainability, 12(5), 597-610.

weighing economics, environment, and social outcomes, it results in constituents taking a position rather that devising comprehensive approaches. This is important to green infrastructure because leaders and communities have to outline clear objectives from early on in the planning process if they are the be effective in creating an implementable plan that meets the desired needs.

Green infrastructure falls into sustainability and watershed planning, yet sustainable sources of funding are lacking. Unlike other forms of infrastructure, there are options and green infrastructure doesn't take on a "one size fits all approach" to its construction or maintenance.[28] This makes the budgeting and funding for lifetime maintenance largely unknown and more experimental. Furthermore, maintenance is dependent on the weather, seasonal changes, and rain events. A lack of data and information on cost and performance, on a regional and site level, increases the risk that green infrastructure will or will not work in the context.[29] Questions of if it is appropriately sized for today and the future continue to arise. For neighborhoods that have not been fully developed, a new development in proximity to a green infrastructure asset like a bioswale or bioretention area could increase the volume it sees and could damage it. With a large risk to implement green infrastructure, cities often need exterior funding sources to support the construction. Unfortunately, it wasn't until 2015 that there was a federal fund to support financing of green infrastructure, even though it has been an alternative for decades and the EPA has supported its implementation since 2007.[30] With a lack

[28] Staddon, C., Ward, S., Vito, L., Zuniga-Teran, A., Gerlak, A., Schoeman, K., . . . Booth, A. (2018). Contributions of green infrastructure to enhancing urban resilience. Environment Systems and Decisions, 38(3), 330-338.
[29] Dhakal, & Chevalier. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management, 203(Pt 1), 171-181.
[30] Cutchin, Caitlin. (2015). Investing in resiliency: Prioritizing water systems and investing in green infrastructure. Sustainable Development Law & Policy, 16(1), 14.

of support and funding from the federal and local governments, green infrastructure projects are often supported by private and not-for-profit dollars resulting in a dispersed system that lacks the effectiveness to make a regional impact.

One of the primary pitfalls of green infrastructure is its contribution to displacement. This displacement occurs through gentrification and "green washing". Green washing in particular associates' green infrastructure to be for a public good but is intended to be for economic profit and socially affluent.[31] While both are funded with public dollars, the difference between the two is scale and timing. Gentrification spurred by public investment results in a community being priced out of either buying into a neighborhood that they once could afford or no longer being able to afford rising rents.[32] This occurs following the announcement of investment or after the opening. Green washing occurs early on in the planning process. In the context of green infrastructure, and example of green washing would be when public investment is followed by private sector announcement of a large development project neighboring it. While the investment may solve the issues of stormwater, the investment is the result of profitable economic opportunities for the private and the public sector. The greatest ugly truth is that in either circumstance, the people present in the community prior to the investment, the people that participated in the community engagement, and the people that supported the investment will not reap the benefits of access to the investment because they simply can't afford the services or the price tag to reside there.

[31] Staddon, C., Ward, S., Vito, L., Zuniga-Teran, A., Gerlak, A., Schoeman, K., . . . Booth, A. (2018). Contributions of green infrastructure to enhancing urban resilience. Environment Systems and Decisions, 38(3), 330-338.
[32] Rouse, D. (2018). Social Equity, Parks and Gentrification. Parks & Recreation, 53(7), 38-39.

Clear understanding of the scope and capabilities of green infrastructure continues to be a drawback. Green infrastructure as a strategy is an Adaptation measure rather than a capacity measure. Its intent is to not store and divert, but to replace and restore natural processes that contain and treat stormwater on site. Even though industry and research acknowledge that grey infrastructure diverts water to containment areas that are built undersized, grey infrastructure continues to be implemented more than green.[33] A focus on new capacity does not solve the environmental challenges or addresses the influx of stormwater cities will see with the removal of impervious surfaces, but it is a more common strategy and appears "simpler" to handle one additional asset rather than hundreds of additional assets. While research acknowledges the potential benefits of green infrastructure, there continues to be unvalidated estimation of its capabilities. Considering climate change factors like urban heat island effect, flood risk management, and ecosystem resilience, green infrastructure does in theory improve the circumstances.[34] However, there is little evidence to affirm that green infrastructure directly contributes climate change adaptation. As more experimentations of green infrastructure become implemented, they can be studied, but adoption of this practice will continue to be minimal until there is more evidence of success.

Policy in the past has made it difficult to implement green infrastructure on the scale necessary. While the public right of way is cumulatively a high quantity of land that cities own, there is a breadth of existing infrastructure and future infrastructure like electricity, gas, transit,

[33] Dong, X., Guo, H., & Zeng, S. (2017). Enhancing future resilience in urban drainage system: Green versus grey infrastructure. Water Research, 124, 280-289.
[34] Sussams, Sheate, & Eales. (2015). Green infrastructure as a climate change adaptation policy intervention: Muddying the waters or clearing a path to a more secure future? Journal of Environmental Management, 147, 184-193.

and water that it has to support in the same footprint. Adding new forms of infrastructure that do not follow the existing typologies are challenging to accommodate. Under constitutional laws, cities cannot occupy or take private property without due process and just compensation.[35] Because these properties are individually owned, cities would need to enter discussion with each owner which is an extensive, expensive, and cumbersome process. Even with federal support and funding, it is not the decision of the federal government to make implementation strategy decisions.[36] Federal agencies may encourage the use of alternative technologies and infrastructure, but city policy and regulations are the deciding bodies. If city code is unclear or doesn't recognize the new technologies and governing bodies and local leadership do not support it, it is difficult to pass preliminary planning stages. Even when there is a desire to create policy and the governing bodies support it, there still may be lack of integration with other planning efforts. In the analysis of green infrastructure plans across Europe, they found several similar conflicts. The greenspace planning policy lacked integration with stormwater management which narrows its abilities and focus to biodiversity, health, and adaptation to climate change.[37] Policies may also lack long term planning approaches and sustainable connections. With evolving changes in government structures, planning efforts dissipate following a change in leadership. These problems manifest in unalignment with code, lack of communication between departments and understanding of considerations like long

[35] "The Constitution." The White House, The United States Government, www.whitehouse.gov/about-the-white-house/the-constitution/.
[36] Dhakal, & Chevalier. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management, 203(Pt 1), 171-181.
[37] Davies, C., & Lafortezza, R. (2017). Urban green infrastructure in Europe: Is greenspace planning and policy compliant? Land Use Policy, 69, 93-101.

term maintenance.[38] These challenges highlight the need for greater connections between the professions and organizations to realize policy to fulfill the knowledge gap and continue planning efforts surpass the initial stages and continue with various periods of leadership.

While climate change continues to be a looming threat to society, an understanding of the impacts of urban growth on infrastructure systems is severely underestimated. With a projection that 65% of populations will be in cities, cities have to prepare for a diversity of growth.[39] Growth can be infill, along the edges, within existing structures with new units and new living arrangements. Ultimately, growth will occur unbalanced and uncontained to a defined boundary. This growth will impact all aspects of city's infrastructure and without adequate planning for this growth, it will disrupt flows within the city and interfere with resident's quality of life. Even with this threat, there is a continued lack of understanding around these realities.[40] Emerging studies have been attempting to address this conflict. A study looking at these potential impacts on the relationship between system resilience and infrastructure cost found that urbanization causes a 17% decrease in system resilience. When comparing grey to green infrastructure improvements, the study found that a 30% and 33% increase of system resilience occurred when implementing green roofs and permeable pavement, while the operation of four storage tanks would result in a 17% improvement of system resilience. The study found that green infrastructure strategies were more effective than traditional grey strategies. If we are to adequately plan for green infrastructure with urban

[38] Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management,203(Pt 1), 171-181.
[39] "Quito Declaration on Sustainable Cities and Human Settlements for All." New Urban Agenda, United Nations, 2017, pp. 2–10.
[40] Dong, X., Guo, H., & Zeng, S. (2017). Enhancing future resilience in urban drainage system: Green versus grey infrastructure. Water Research, 124, 280-289.

growth, we need to implement policy that sets higher standards for development and addresses adaptation for present and future challenges when the opportunities arise if we are to sustain our quality of life in cities.

3.5 Investments- Requirements and Opportunities

Green infrastructure requires investment in order for it to be sustainable, effective, and a viable long term strategy. The most common idea of investment is financial. As previously described, sustainable funding resources are required to make implementation of green infrastructure at all scales possible. By investing in green infrastructure, there are opportunities to see a return on investment. A study done by University of Helsinki and Finnish Meteorological Institute investigated how spatial location of parks, forest, and fields effect apartment prices in Helsinki, Finland. They hypothesized that close proximity to urban green space can assist in funding larger green infrastructure projects by raising the property values. Using hedonic models, the study was able to capture the socioeconomic effects by analyzing market prices for apartments. The study found that not all types of green spaces capture equal value at the same distance. Properties in close proximity to the central business district that were also close to forest had the highest apartment rates. Nevertheless, fields have the highest apartment rates as distance away from the central business district increased.[41] While conflicting, it does support that better decision making should and can be made about the level of investment in parks relative to the distance from the central business district. It is important to highlight that the study lacked to discuss the average initial level of investment and yearly

[41] Votsis, A. (2017). Planning for green infrastructure: The spatial effects of parks, forests, and fields on Helsinki's apartment prices. Ecological Economics, 132(C), 279-289.

maintenance cost of each type of greenspace. It also lacked discussing the ownership of the greenspace and identify what percentage is privately owned versus public. A better understanding of these factors would better support the findings and give more insight for cities considering large green infrastructure projects. It also highlights the potential return on investment. For instance, according to this analysis, it is not wise to fund an astronomical financial investment to a green space project in the suburbs because the likelihood is that the return on the investment is minimal. Return on investment is particularly significant if cities are using tax increment financing strategies to fund large green infrastructure projects. Tax increment financing uses the increases in the property tax revenue to fund designate projects within a defined boundary of the site. To further support the use of tax increment financing, research has been done to analyze the value capture. It was found through regression analysis that land value of properties within 400 feet of park space capture the greatest value of the amenity. The value continues to drop till 2500 feet where after that point the value is negligible.[42] Having an adequate knowledge of how the values of properties change when public investment in green space occurs will help cities to invest appropriate amounts of public investment based on the distance from the site. It will also help cities project how long the tax increment boundary should occur.

With advance in technology, cities have the opportunity to improve administration procedures and make more informed decisions. Appropriate placement of green infrastructure requires an adequate understanding of the land use and the topography. A landscaped based

[42] Crompton, J. (2005). The impact of parks on property values: Empirical evidence from the past two decades in the United States. Managing Leisure, 10(4), 203-218.

approach to planning encourages detail mapping and documentation of the landscape. With faster internet speeds and increasingly powerful software, it's easier to document and analyze the landscapes' existing conditions relative to current land use. A study conducted in collaboration with several universities in Manchester, United Kingdom sought to understand what type of analysis could be produced with current available data.[43] They had access to both spatial temporal data and census data along with accurate land use data. They found that with accurate mapping of the landscape, cities can be more informed and accurately assess opportunities to integrate and implement green infrastructure in the best suited and appropriate manners. Researchers also found that "land use, land cover and socio-geographic elements, in combination rather than exclusion, supports a social–ecological perspective" however the perspective is solely dependent and limited based on the detail quality of the data set and the initial considerations of the data.

With investments in high quality data for the purposes of planning, cities can use the data to better capture the value of public investment. Previous studies have highlighted that in order to capture the value of green infrastructure, the equation of the value needs to be revised.[44] A study of green infrastructure in Johannesburg, South Africa highlighted the need to redesign cities' budgeting, accounting and municipal asset management processes to better accommodate green infrastructure. Accounting for factors like age, quality, and health equates to varying values and appreciation. Instead of envisioning green infrastructure as amenities, the

[43] Matthew Dennis, David Barlow, Gina Cavan, Penny A. Cook, Anna Gilchrist, John Handley, . . . Sarah Lindley. (2018). Mapping Urban Green Infrastructure: A Novel Landscape-Based Approach to Incorporating Land Use and Land Cover in the Mapping of Human-Dominated Systems. Land, 7(1), 17.
[44] Schäffler, & Swilling. (2013). Valuing green infrastructure in an urban environment under pressure — The Johannesburg case. Ecological Economics, 86, 246-257.

study urges governments to think of them as assets. These assets need to be maintained in order to be productive and beneficial to society. While there is no current accounting system to measure these factors, as the use of green infrastructure continues to increase, there should be efforts to create a system. This system with also contribute to equating property values in proximity to small as well as large green infrastructure more accurately. Accurately accounting the value of green infrastructure allows us to compare traditional grey infrastructure to green infrastructure techniques. For governments in developing countries, the risk of adopting a new technology that is not as well studied but is proven to be cost effective will help encourage decision making that implements green infrastructure into its stormwater management system. With an understanding of the opportunities and pitfalls of green infrastructure, we can assess and analyze why and how cities implement green infrastructure. The following sections will describe the methods I will be taking to analyze green infrastructure plans for three metro areas as well as commonalities between them that led them to commit to this strategy approach.

4.0 Combined Sewers Systems

4.1 What are CSOs

For urban centers that are facing the challenges of managing stormwater and waste water, implementing infrastructure is a gamble. For the 722 cities in the US with combined sewer systems, they have been working with the EPA for decades to resolve the negative impacts and effects that these systems have on the environment.[45] Combined sewer systems are a problem

[45] Hu, Winnie. "Please Don't Flush the Toilet. It's Raining." The New York Times, The New York Times, 2 Mar. 2018, www.nytimes.com/2018/03/02/nyregion/new-york-reduce-water-use-in-rainstorms-flush.html.

at the local, state, and federal level. The central sewer system is designed to treat both stormwater and sewer water in a combined treatment plant. The idea of the system is that it reduces the cost of the treatment system by reducing amount of piping and cost of separating treatment plants. However, when there are storm events and the system is overloaded, overflows of human waste, industrial waste, and stormwater are deposited into surrounding waters (Figure 1). This cost difference emerged in consequences for the city, state, and the environment.

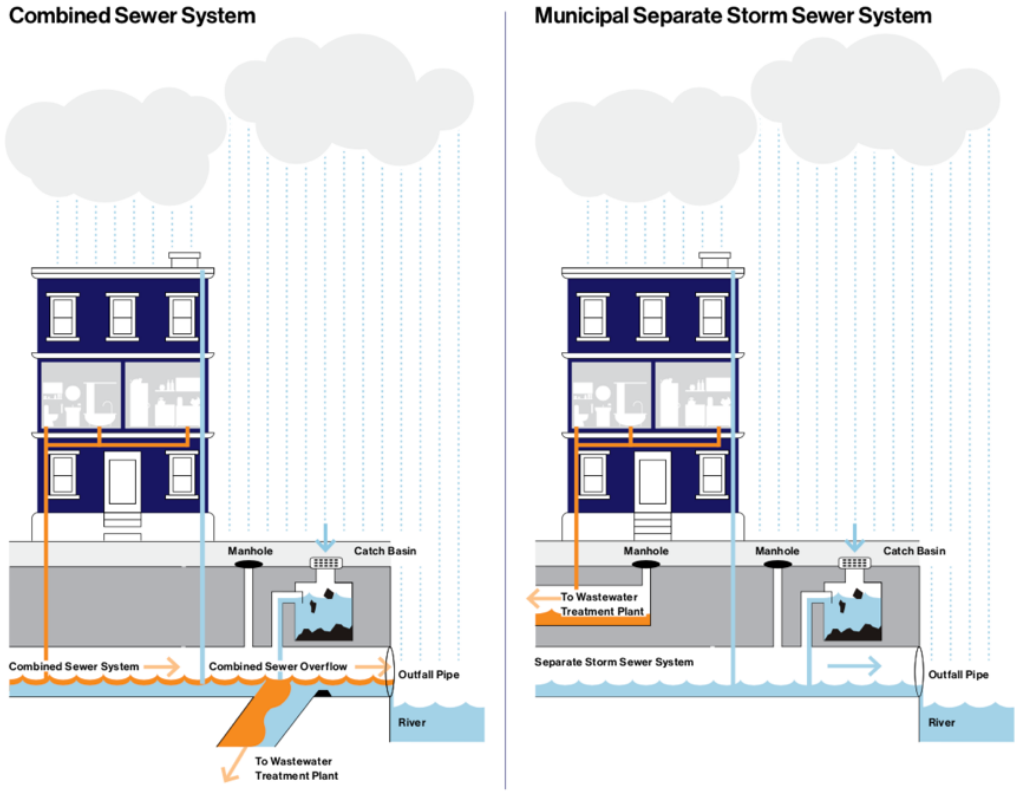

Figure 1: The diagram showcases the differences between a Combined Sewer System and Separated Storm Sewer System

Consequences of combined sewer overflows have been heavily documented at the local and federal level.[46] Environmental degradation to native species, coast, and waters is clearly documented by the EPA. Water deposited from CSOs is a mix of both sewage and stormwater. This water can be a mix of untreated human and industrial waste, pollutants, and debris. During a CSO event, there is very little way to measure to what amount of each is being deposited.

The problem of combined sewer overflows is an everyone problem. Environmental protection is a concern of federal, state, and local governments. The impacts on the economy due to the lack utilization of natural resources like beaches and trails results in a loss of economic production for businesses are local concerns. Devaluing of property values and negative health impacts on the communities in close proximity to contaminated water sources is a concern to citizens as they are directly impacted, but also all level of governments for economic and health and welfare concerns. Exposure to contaminated waters is dangerous and a public health concern. Waterborne infections including hepatitis, gastroenteritis, as well as skin, wound, respiratory and ear infections are common from ingesting contaminated water and inhaling water vapors.[47] Contracting these infections may result in the need for medical treatment. The impacts of combined sewers systems have resulted in them being managed and regulated at a federal level.

4.2 Stormwater vs Sanitary Wastewater

[46] "National Compliance Initiative: Keeping Raw Sewage and Contaminated Stormwater Out of Our Nation's Waters." EPA, United States Environmental Protection Agency, 7 Sept. 2018, www.epa.gov/enforcement/national-compliance-initiative-keeping-raw-sewage-and-contaminated-stormwater-out-our.

[47] "National Compliance Initiative: Keeping Raw Sewage and Contaminated Stormwater Out of Our Nation's Waters." EPA, United States Environmental Protection Agency, 7 Sept. 2018, www.epa.gov/enforcement/national-compliance-initiative-keeping-raw-sewage-and-contaminated-stormwater-out-our.

Combined sewer systems are responsible for transporting wastewater to treatment plants, but there are unique differences in the types of water treated. Combined sewer systems mix both sanitary wastewater and stormwater. Sanitary wastewater is comprised of grey water and black water. Grey water refers to water from sinks, showers, and washing machines.[48] Black water refers to sewage. Black water comes specifically from toilets and kitchen sinks.[49] Stormwater contents vary. Stormwater at its core is a mix of trash, chemicals, oils, and dirt. Dependent on the exposed sites, this water can be a mix of untreated human and industrial waste.[50] During a CSO event, there is very little way to determine and measure to what amount of each is present in the water. The commonality between the types of water is that they contain pathogens, floatables, and nutrients that without treatment would be harmful for consumption or disposal in the natural environment.[51]

4.3 Treatment

Treatment of water in combined sewer systems is an intensive process. Water treatment consists of three phases- physical, biological, and chemical.[52] The physical phase includes the removal of large solids and floatables from the system and treats the water rather than debris. The biological process removes bacteria and small organisms or pathogens from the water that would be otherwise present in natural processes. The chemical phase utilizes natural and

[48] "Municipal Wastewater." EPA, Environmental Protection Agency, 29 Aug. 2018, www.epa.gov/npdes/municipal-wastewater.
[49] "Guidance Manual for Separation of Graywater from Blackwater for Graywater Reuse (WERF Report INFR4SG09a)." EPA, Environmental Protection Agency, 22 Apr. 2015, cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=247864.
[50] "NPDES Stormwater Program." EPA, Environmental Protection Agency, 14 Sept. 2018, www.epa.gov/npdes/npdes-stormwater-program.
[51] "NYC Stormwater Management Program." NYC Department of Environmental Protection, 2018, (pg. 3-36). http://www.nyc.gov/html/dep/pdf/water_sewer/NYC_SWMP_Plan_Full- 08012018.pdf
[52] Primer for Municipal Wastewater Treatment Systems, EPA, Sept. 2004, www.epa.gov/sites/production/files/2015-09/documents/primer.pdf.

synthetic chemicals to remove nutrients from the water. This treatment is commonly conducted with chlorine, ozone or ultra violet radiation. With combined sewers systems, the treatment follows similar process as sanitary sewer systems, but they are required to be more intensive due to the potential industrial waste, oil, and other unknown pollutants that may be present. Even though these treatments are effective they can have negative environmental effects on the natural environment and organisms if exposure is not contained. Following the treatment, water is deposited into natural water bodies.

4.4 Current Conditions

As infrastructure continues to age and populations continue to move to urban centers, cities are faced with expensive upgrades and repairs as it applies to basic infrastructure in cities. Today, cities are in critical states and need effective, implementable, and sustainable tools to improve conditions. In 2007, the US Environmental Protection Agency's Assistant Administrator Benjamin Grumbles released the first of several memorandums promoting the use of green infrastructure.[53] The memo highlighted that green infrastructure is both "cost effective and an environmentally preferable approach" to reduce the impact of excess stormwater is water treatment systems. While cities with combined sewer systems may find this solution an alternative for separating the sewer system entirely, Grumbles indicates that green infrastructure is most effective when paired with other "decentralized storage and infiltration approaches". Supporting the implementation of green infrastructure was continually validated in 2015 under the Build America Initiative created under the Obama administration. The

[53] Grumbles, Benjamin H. Memorandum: Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and Other Water Programs. United States Environmental Protection Agency, Mar. 2007.

initiative created a state revolving fund that provided low interest loans for water resiliency and infrastructure projects that incorporated climate change considerations.[54] From 2007 to 2011, the EPA continued to work within the agency regional offices, and state administrations to develop planning and design frameworks for implementing green infrastructure.[55] With financial and legislative support from the federal government, green infrastructure can be supported as a viable strategy. The following sections will discuss how we will analyze three cities plans for implementing green infrastructure to manage stormwater and reduce their production of combined sewer overflows.

5.0 Case Study Cities

5.1 Methods

Understanding how to allow even cities with infrastructure and water quality challenges to use an alternative that has been endorsed by the EPA is a challenging task. One of the principle challenges of this is available precedents. The use of green infrastructure has predominantly been used in an international context and at smaller scale than some of the urban centers in the US. While proven to be both cost effective and environmentally friendly, the prominent question is will green infrastructure be effective at the urban scale. For this reason, very few cities have adopted comprehensive green infrastructure plans, however, there are an increasing number of cities that are beginning to draft plans including green infrastructure. While supported as an alternative on the federal level, I think it is important to conduct an *ex*

[54] Cutchin, Caitlin. (2015). Investing in resiliency: Prioritizing water systems and investing in green infrastructure. Sustainable Development Law & Policy, 16(1), 14.
[55] Stoner, Nancy. Memorandum: Protecting Water Quality with Green Infrastructure in EPA Water Permitting Enforcement Programs. United States Environmental Protection Agency, Apr. 2011.

post analysis of the outcomes of these plans to understand do precedent examples of cities' green infrastructure plans achieve a balance between social, economic, and environmental factors and if so how. For this study, I will be evaluating New York City, Washington DC, and New Orleans. While these cities are similar in facing the challenge of resolving and retrofitting their combined sewer system, they are different in metro area size, population and relationship to the water.

I utilized the triple bottom line framework to compare three cities green infrastructure plans. This framework describes that there should be equal benefit socially, economically and environmentally and therefore creating a nexus that is the best strategy to take. While this is a business strategy approach, it is often taken into account for decision making in the public sector. In order to answer the previous questions using the framework, I narrowed the factors that were being evaluated based on the categories of social, economic and environmental (Figure 2). These factors focus especially on the implementation strategy to forecast the impacts on the community. As highlighted previously, one of the primary downsides of green infrastructure is its contributions to gentrification. This can be from variety of factors but is most criticized for its large amount of public investment in a site, lack of community input in the planning process, and the desire of the private sector to capture the value of the amenity. These factors will highlight actions that may or may not influence the negative outcome of gentrification. I utilized civil action suit documents, consent orders, green infrastructure plans, and all other documents describing the results of the plan to evaluate the approach and implementation of the green infrastructure plan for three cities. In the following section, I will

be evaluating three metropolitan areas plans for implementing green infrastructure using these factors.

Social Factors	Economic Factors	Environmental Factors
Establishing Long Range Planning	Sustainable Funding Sources	Regional Planning Efforts
Engagement of the Public	Innovation	Research Driven Process
	Variety in Scales of Implementation	Enforcement Capility

Figure 2: The categorization of the factors used to evaluate three cities' green infrastructure plans based on the overarching principles- social, economic and environmental.

5.2 New York City

5.2.1 Why/ Intent of the plan

New York City has a water quality problem which is directly contributed to by its combined sewer system and resulting overflows. In New York City, this problem manifested in an aging and ineffective wastewater management system.[56] While the City did expand the infrastructure by districts, the future growth of the population of the City and the development could not have been projected to forecast the future problems. The central sewer system that supported the wastewater management slowly became vulnerable with a larger population to support, more impervious surfaces, and higher development. With less permeable surfaces for water from homes and rain events to go to, the water would be diverted to the combined sewers and then deposited into the surrounding bodies in combined sewer overflows or *CSO*s.

[56] "2017 Infrastructure Report Card: Wastewater." Infrastructure Report Card, ASCE, 2017,www.infrastructurereportcard.org/wp-content/uploads/2017/01/Wastewater-Final.pdf.

While the City has been working to fix the problems of its sewer system since the 1980s, the New York City Department of Environmental Protection or *DEP* failed to comply with deadlines agreed to with the New York State Department of Environmental Conservation or *DEC* in its long term control plan. This plan outlined the processes the city to would use to upgrade its sewer system. This failure resulted in a lawsuit filed by the state of New York against the City.[57]

5.2.2 Approaches to implementation

Prior to 2010, the city was implementing traditional grey infrastructure only improvements.[58] Infrastructure improvements would increase the efficiency of waste treatment plants and fund the development of new plants. Nevertheless, the city of New York noted in the *2011 Green Infrastructure Plan Update* that it would have to spend an additional 2 billion dollars to fund improvements and the construction of new treatment plants.[59] Alternative infrastructure improvements like green infrastructure provide an opportunity to improve the conditions of the sewer system with less capital investments while improving quality of life. Quality of life also applies to the sustainability of the city as a whole. Departments across the City from Environmental Protection to Economic Development to Harbors and the Office of Sustainability all depend on the health of the City.[60]

[57] State of New York Department of Environmental Conservation v. The City of New York and The New York City Department of Environmental Protection, DEC Case No. CO2-20110512-25. October 2011, http://www.nyc.gov/html/dep/pdf/green_infrastructure/CO2-20110512-25.pdf
[58] State of New York Department of Environmental Conservation v. The City of New York and The New York City Department of Environmental Protection, DEC Case No. CO2-20110512-25. October 2011, http://www.nyc.gov/html/dep/pdf/green_infrastructure/CO2-20110512-25.pdf
[59] "2011 NYC Green Infrastructure Plan Update." NYC Department of Environmental Protection, 2011, http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2012.pdf
[60] "New York Harbor: Healthier Than It's Been in More Than a Century." Office of the Mayor, City of New York, 7 Dec. 2017, www1.nyc.gov/office-of-the-mayor/news/753-17/new-york-harbor-healthier-it-s-been-more-century.

Following the lawsuit, the city consented to implementing a green infrastructure plan and programming in addition to existing grey infrastructure projects in a ground breaking agreement.[61] This decision deferred 2 billion dollars from solely wastewater treatment plants and will be multifunctional by improving the quality-of- life benefits of citizens by "improving air quality, increasing shading, increasing property values, and improving our streetscape". As I continue this policy analysis, I will be evaluating the initiatives implemented in the green infrastructure plan from 2011 to 2017.

5.2.3 Goals and Evaluation Criteria

While the goals of this program were targeted at reducing the combined sewer overflow events and the negative impacts, the lawsuit set explicit criteria and milestones over a period of years .[62] One of the primary criteria was to identify appropriate CSO controls necessary to achieve waterbody specific standards consistent with EPA's 1994 CSO Policy and subsequent guidance. This is key because not all types of green infrastructure may be appropriate for use based on factors like site conditions, cost, monitoring accuracy, and knowledge of the construction industry in the region. The consent order also established an overarching long-term goal of "managing one inch of precipitation on 10% of impervious surfaces in combined sewer areas and a calculation of the equivalent CSO volume reduction associated with that green infrastructure application by December 31, 2030 with green infrastructure". This percentage was measured based on a city-wide baseline based on the conditions on January 1,

[61] "NYSDEC & NYCDEP Announce Groundbreaking Agreement." New York State Department of Environmental Conservation, 13 Mar. 2012, www.dec.ny.gov/press/80919.html

[62] State of New York Department of Environmental Conservation v. The City of New York and The New York City Department of Environmental Protection, DEC Case No. CO2-20110512-25. October 2011, http://www.nyc.gov/html/dep/pdf/green_infrastructure/CO2-20110512-25.pdf

2010. There are several milestones set to meet the overarching goal. These milestones are as followed

- Managing stormwater the equivalent of one inch of precipitation on 4% of impervious surfaces in combined sewer areas by December 31, 2020
- Managing stormwater the equivalent of one inch of precipitation on 7% of impervious surfaces in combined sewer areas by December 31, 2025

While not explicitly stated in the consent order, there are secondary benefits that can be accomplished with the implementation of green infrastructure. Aspects of the quality of life like air quality, access to shading, and the urban streetscape can be improved by investing in green infrastructure. These improvements are also reflected in increased property values across the City.[63] Creating a more sustainable New York City- increasing urban greening, reducing urban heat island effect, and providing more habitat for birds and pollinators around the City- is also linked to the utilization of green infrastructure and has positive effects.[64] While these benefits may not be of concern to the NYC Department of Environmental Protection, they may be of importance to other offices in the City like the Office of the Mayor and the Office of Resilience.

5.2.4 Analysis and Comparison

In order to analyze the green infrastructure plan, I examined all of the New York City's green infrastructure plans published from 2011 to present. I cataloged the programs and the policies

[63] "2011 NYC Green Infrastructure Plan Update." NYC Department of Environmental Protection, 2011, http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2012.pdf
[64] Staddon, C., Ward, S., Vito, L., Zuniga-Teran, A., Gerlak, A., Schoeman, K., …Booth, A. (2018). Contributions of green infrastructure to enhancing urban resilience. Environment Systems and Decisions, 38(3), 330-338.

implemented throughout the years and the outcomes of those programs and policies (Figure 5). From this examination, several revelations became apparent.

Diversity of Projects

The city implemented a variety of programs and policies for public and private property. The projects include grants, retrofits, tax incentives, and taxes to encourage better behavior. Efforts to retrofit were on public and private property. The city retrofitted public buildings like offices, schools, and playgrounds to better manage stormwater on site. Retrofits to the sewer system in the public right-of-way were implemented to reduce the stormwater entering the sewer system. These retrofits create stormwater assets, like bioswales and storm chambers, while also separating the combines sewers pipes. These retrofits were implemented across the city in the combined sewer areas (Figure 3). Retrofits on private property were regulated by legislation changes called the Stormwater Performance Standard or the "Stormwater Rule". The Stormwater Rule requires new house and/or site connections to the City's combined sewer system to comply with stricter stormwater release rates. This legislation promotes greater on-site stormwater detention. If a property was to be renovated past a threshold, it was required to meet the new standards. Tax incentives were used to encourage and incentivize better behavior in the new buildings. This was implemented for the Green Roof tax abatement which provides tax abatement up to $100,000 for approved projects with a green roof. The City also passed legislation to approve a discharge fee on properties, specifically stand-alone parking lots, that contribute runoff to the City's wastewater system and do not receive or pay for city water service that they contribute to.

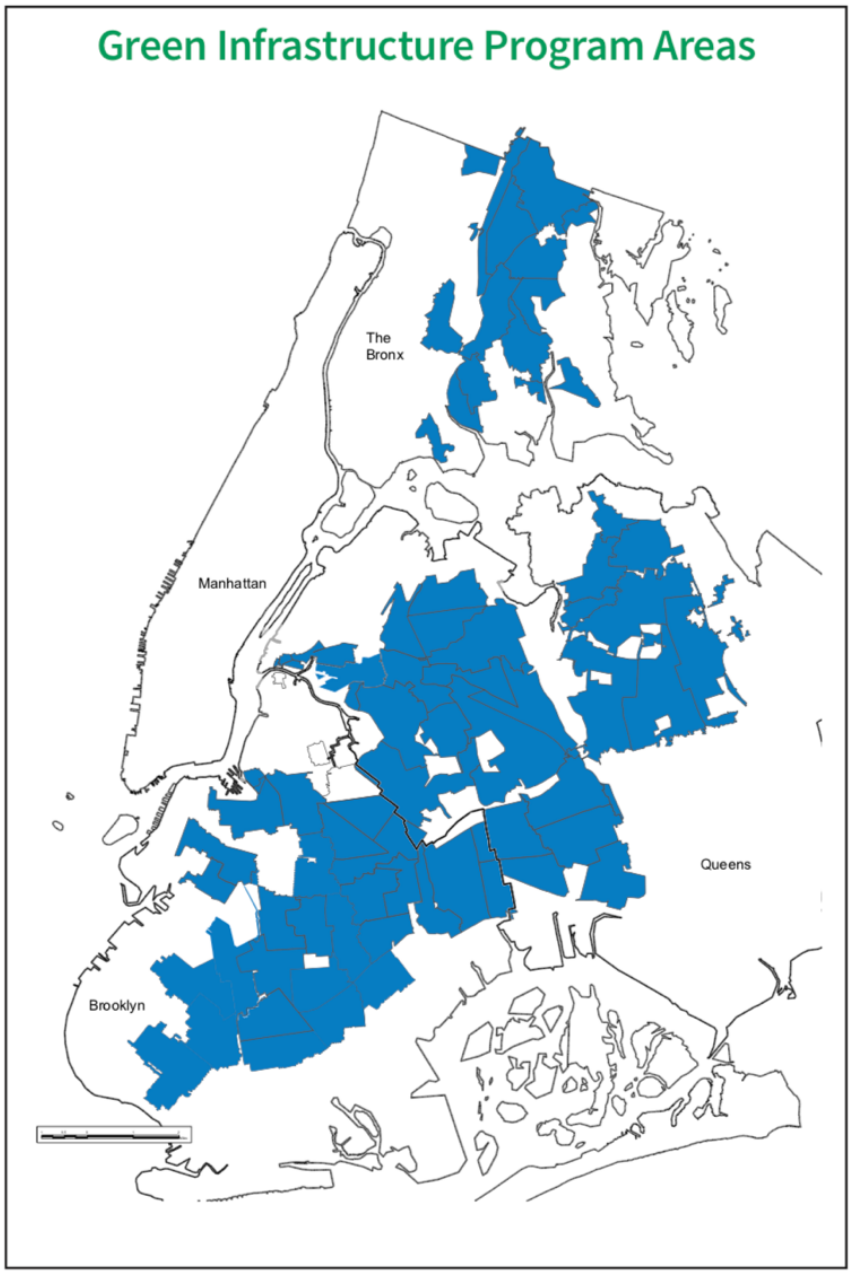

Figure 3: A map of areas green infrastructure has been implemented in New York City.

Problems of Underreporting

While the City was pursuing a variety of projects, there is a great deal of underreporting. The *green acre* calculation is the method the City is utilizing to account for its progress towards the goals outlined in the consent order. In the first year, the City performed research to identify

appropriate infrastructure to be utilized throughout the implementation of the green infrastructure plan. During this time, they were able to measure and analyze the effectiveness of the potential assets relative to sizing. Following this analysis, the City proposed pursuing an aggressive implementation strategy from 2013 to 2030 (Figure 4). Nevertheless, the city has not documented the greened acres for all the projects and policies it is funding.

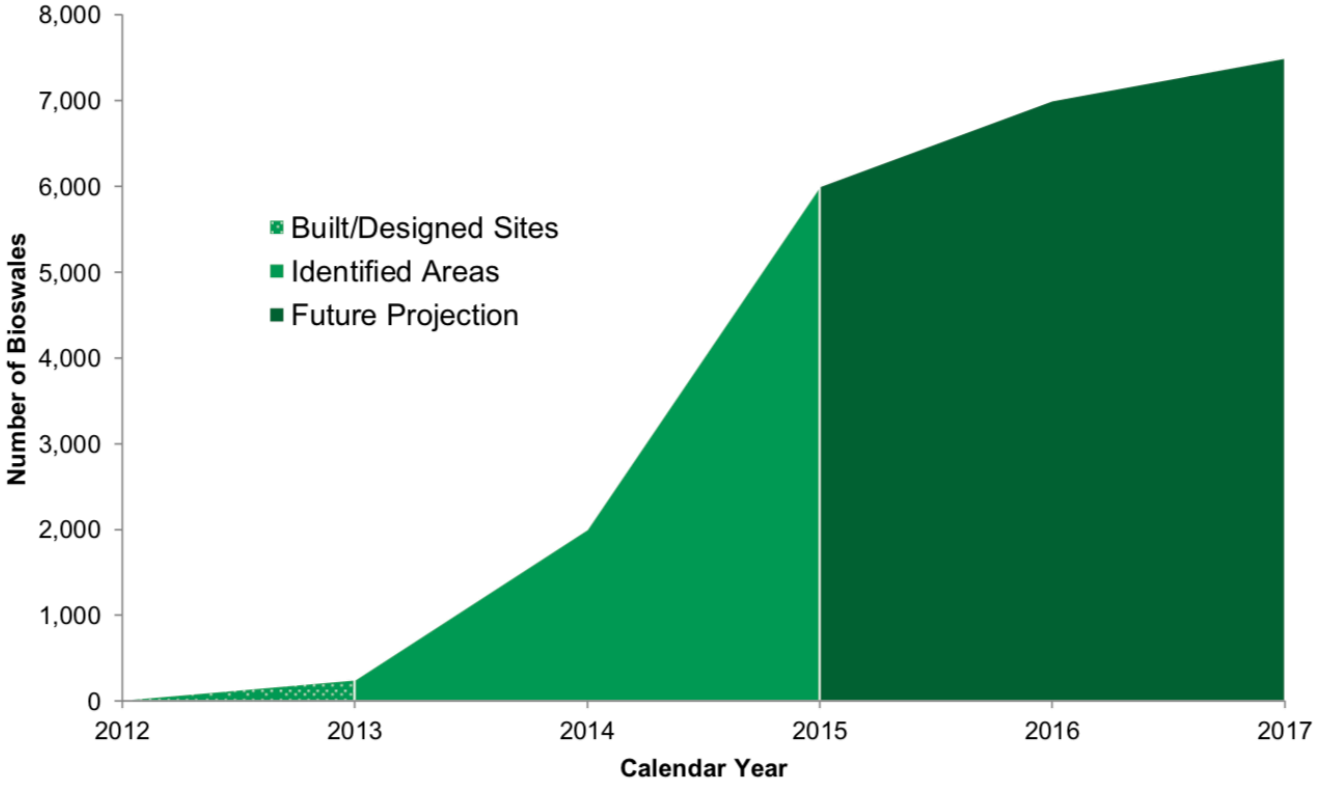

Figure 4: New York City's Implementation Strategy for green infrastructure to meet their consent order with the EPA.

Problems of Underspending

While the city is required to budget money to these efforts in the consent order, there is a problem of underspending on a yearly basis. With the exception of 2013, the City's Department of Environmental Protection had spent less than 10% of the year's budget allocated for the green infrastructure plan. While not necessary for the analysis, the City has not documented

the revenue received from the parking lot pilot program or the money "given" via the green roof tax abatement.

Lack of Community Engagement

Community engagement in the planning process has always been a part of the green infrastructure plan. Forms of community engagement include establishing a task force, education, generating documents, ceremonies, and presentations. Nevertheless, the attendance of this engagement has remained stagnant. It is important to note that documentation of attendance was not reported in the green infrastructure plan updates until 2015. Of the reported attendance, most events received attendance under fifty individuals. Board meetings, presentations, and opening ceremonies received large turnouts for the events reported.

Based on the analysis, the City is failing to meet one of the primary goals of managing one inch of precipitation on 4% of impervious surfaces with green infrastructure application by December 31, 2020 due to under reporting and/or underspending. This failure is further acknowledged in the 2017 Green Infrastructure Plan with the following statement.

> *Over the last seven years, DEP has learned through experience that the original Green Infrastructure Plan (2010) implementation schedule was too ambitious. Although DEP has made significant progress and continues to design and build green infrastructure, we are expecting to submit a contingency plan for the 2020 target (due in June 30, 2021).*[65]

[65] "2017 NYC Green Infrastructure Annual Report." NYC Department of Environmental Protection, 2016, https://www1.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2018.pdf

In summarizing the efforts completed by the city of New York over the years, I was able to measure what the city has accomplished relative to the overarching goal and the milestones established in the green infrastructure plan and the consent order (Figure 5). As of the last year reported, the City had only achieved 15% of the 2020 goal and spent 2.66% of the total budget allotted from 2011 to 2020. Based on the current spending trends relative to the *greened acres* produced, the city would need to spend 20% of the budget to meet the goal of managing one inch of precipitation on 4% of impervious surfaces in combined sewer areas by 2020.

Year	Total Implemented Projects	Total Greened Acres
2013	268	50
2014	446	75
2015	1,472	179
2017	4,316	467
4% Goal by 2020		3150
Percent Achieved		**15%**
Needed Acres		2683
Pecent of Budget Spent		**2.66%**

Figure 5: A chart summarizing New York City's green infrastructure efforts from 2012 to 2017.

Underreporting while underspending are troubling trends for several reasons. Underreporting makes it challenging to analyze the success of programs and policies relative to the 2030 goals. It also makes it difficult to analyze the spending of the department. Therefore, future goals of managing greater percentage of precipitation of impervious surfaces with green infrastructure

become more difficult to achieve. Underspending of the budget makes it challenging to argue for extensions or revisions of the long term control plan. Questions of if the City made a good faith effort to execute the green infrastructure plan may arise as well.

5.3 Washington DC

5.3.1 Why/ Intent of the plan

While the District of Columbia sought to officially implement green infrastructure as a remedial strategy to manage combined sewer overflows in 2013, it has a history of stormwater management problems dating back to the early 2000s. The District of Columbia sits at the point of conversion for many creeks within the Anacostia River Watershed that feed into the Anacostia River (Figure 6). Due to its mass population, lack of undeveloped land, it has been challenging to manage water produced within its city's boundaries. Nevertheless, once one accounts for the bodies of water that go through the city, the responsibility to manage and protect the water increases. One way of doing this was through the District's combined sewer system. Unfortunately, like other cities across the country, the negative impacts of the combined sewer overflows that occur during heavy rain events cause erosion and pollute water with both non-point and point source pollutants. Even with the circumstances, the District of Columbia remains responsible for these consequences. One of the solutions for resolving the problem was to build a series of underground tunnels to hold up to 193 million gallons of stormwater during rain events.[66] With deadlines from the EPA approaching, it became clear

[66] Anacostia Watershed Society, et al. v. District of Columbia Water and Sewer Authority and The District of Columbia, Consolidated Civil Action No. 1.00CV00183TFH. First Amendment to Consent Decree. January 2016.

that the District needed to seek other opportunities to extend the deadline and manage the flow as well as the capacity of water that needed to be treated.

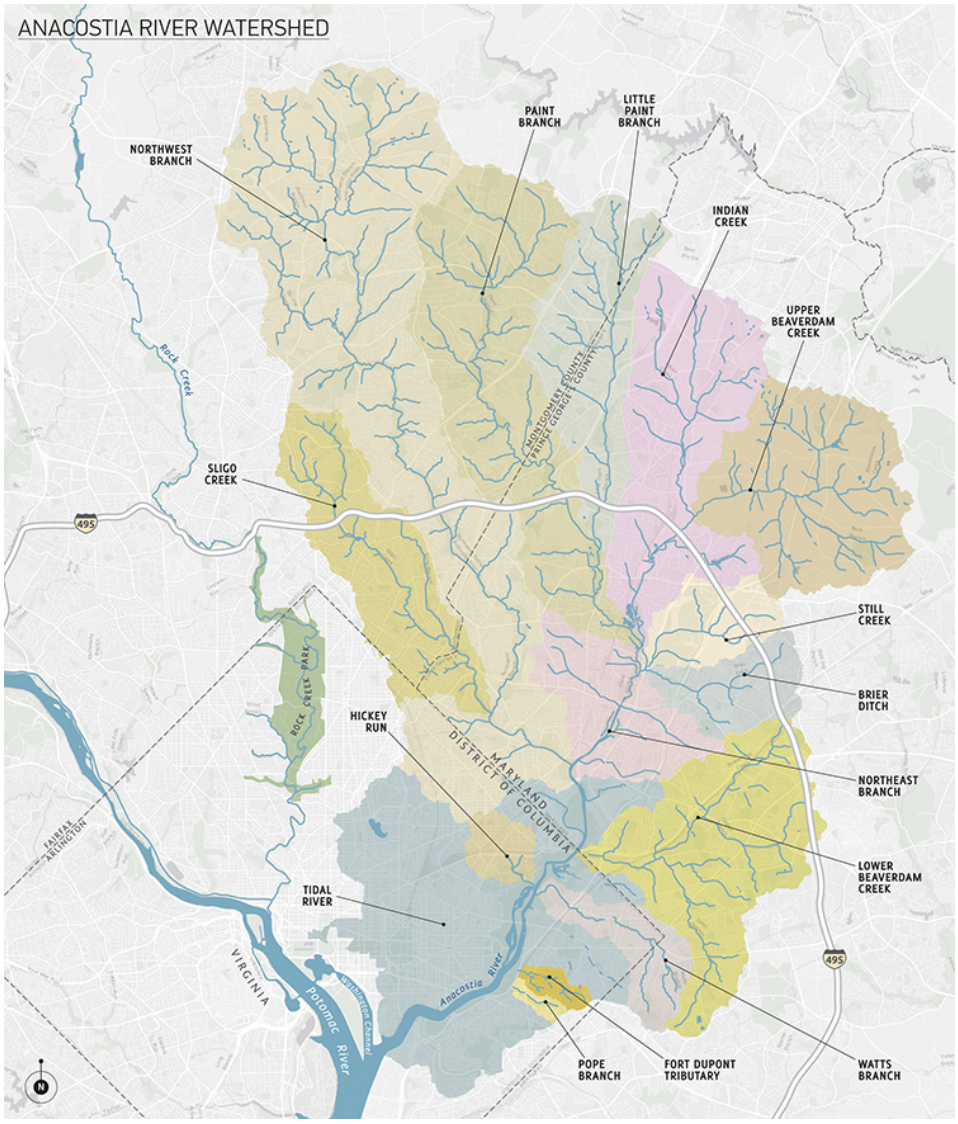

Figure 6: A map showcasing the extent of the Anacostia River watershed.

On February 2, 2000, the Anacostia Watershed Society, Kingman Park Civic Association, American Canoe Association, Friends of the Earth, Sierra Club, and individual citizens filed a Civil Action with the EPA claiming that DC Water had violated the Clean Water Act. They alleged

that DC Water "failed to properly manage operate, and maintain all collection, pumping facilities… and combined sewer system". This civil action resulted in DC Water paying penalties, projects, and establishing a long-term control plan to control combined sewer overflows to the District's waterways. Following the failure to meet the first revision to the Consent Decree, DC Water submitted a second revision including green infrastructure as a strategy in two of the three sewersheds. This change would allow DC Water to reduce the size of its underground tunnels and deliver benefits sooner, better, and more efficiently.[67] With the new approach to managing stormwater, the city launched the DC Clean River Project. The project is intended to provide stormwater management while integrating the natural in into the urban environment, spur local job creation, improve air quality, cool the city, increase wildlife habitat and address climate change.

5.3.2 Approaches to implementation

The District's initial plan for managing stormwater focused on capacity. By integrating underground storage tunnels, the city could expand the capacity of both stormwater and waste water during rain events and reduce the quantity and volume of overflow events. In an effort to address improving water quality, the District began to explore with other strategies outside of the Consent Order requirements. These explorations led to the conclusion that green infrastructure would be equivalent in effectiveness to gray infrastructure in the context of the District of Columbia. Integrating green infrastructure into the District's water management system compromised of new and existing procedures to address public and private property

[67] "GI Program Plan." DC Clean Rivers Project Green Infrastructure Program, District of Columbia Water and Sewer Authority, July 2016, www.dcwater.com/sites/default/files/program_plan_final_with_appendix_2016_0729.pdf.

while addressing the Consent Decree. The second revision of the Consent Decree, that occurred in 2013, was compromised of decreasing the size of the Anacostia River Tunnel and integrating green infrastructure into Rock Creek and Potomac sewersheds along with grey infrastructure to separate stormwater and sewer water (Figure 7). As I continue this policy analysis, I will be evaluating the initiatives implemented in the green infrastructure plan from 2014 to 2018.

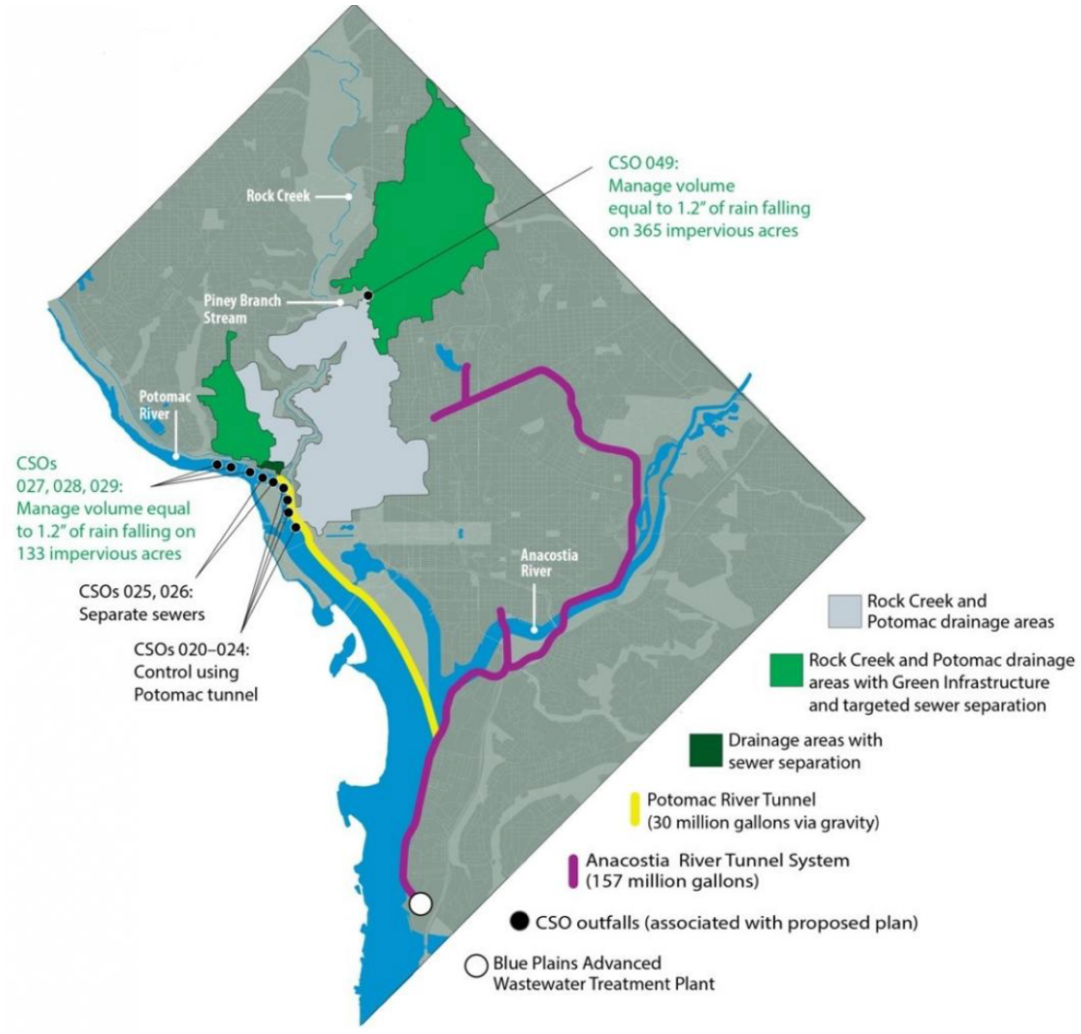

Figure 7: A map showcasing the project changes in the District of Columbia's Amended Consent Decree Requirements.

5.3.3 Goals and Evaluation Criteria

The goals for green infrastructure were explicitly outlined by the second revision to the Consent Decree. For the purpose of this analysis, we will focus on goals for the Potomac and the Rock Creek sewershed. For the Rock Creek Sewershed, DC Water was required to "manage 1.2" of rain falling on 365 impervious acres or 30% of the total impervious acres in the sewershed" by March 2030. Milestones were established leading up to the deadline. The first milestone for this sewershed was to manage 20 acres by March 2019. For the Potomac Sewershed, DC Water was required to "manage 1.2" of rain falling on 133 impervious acres or 30% of the total impervious acres in the sewershed" by March 2027. Milestones were established leading up to the deadline. The first milestone for this sewershed was to manage 44 acres by March 2019. Additional goals outlined within the DC Clean Rivers Project are co-benefits to using green infrastructure and the economic benefits of job creation by DC Water.

5.3.4 Analysis and Comparison

In order to analyze the green infrastructure plan, I examined the DC Clean River Project Green Infrastructure Plan and reviewed DC Water's website for current outcomes of their efforts. I cataloged the actions, programs, and the policies implemented throughout the years and the outcomes of those programs and policies. From this examination, several revelations became relevant.

Narrow Focus

In order to address the Consent Decree, the District focused on the existing sewersheds. While this is effective at addressing the problem within the combined sewers, it is not effective at addressing the water. Considering that DC sits at the bottom of the watershed, it is collecting pollutants and debris throughout the watershed before it even gets to DC. The water also

increases in volume and in speed as it travels through the Anacostia Watershed. Another way of effectively decreasing the volume and addressing the pollutants would be to enlarge the project are throughout the district and even further out into Maryland. Water does not move only within manmade lines; it moves within a geographic boundary already established. While we can address the water within the boundaries of DC, those assets will continue to be burdened overtime if there is not a regional approach to addressing stormwater and runoff.

Detailed Plan

Unlike the New York and New Orleans green infrastructure plan, the DC Water lays out step by step their activities. Within the green infrastructure plan, DC Water sections out areas of implementation by project number. Within those projects, they designate the impervious areas to be managed and projected locations of projects in the public right of way. In order to compute this area, they used GIS to analyze and catalog the square footage of impervious surfaces on public and private property. With this data, it better informs engineers and landscape architects where to effectively place green infrastructure and appropriately size them to manage the volume of water they are likely to see rather than sizing infrastructure by available area. This data also gave the organization the ability to place assets where they can divert water from the sewers and reduce the volume that enters into the sewer system. These efforts effectively address both water quality and reducing capacity in order to reduce overflow events.

Building on the Existing

Rather than piloting a program of its own, the District was informed by other cities efforts and departments within the city. DC Water consulted the department of transportation, energy

and the environment and water to analyze the opportunities, conflicts and limitations of implementing green infrastructure into the city's fabric. They consulted national examples of green infrastructure manuals like New York City and Philadelphia for insight of best practices that ensure public safety, quality and effectiveness in the public realm. Lastly, DC Water referenced existing programs like the Downspout Disconnection program to analyze how to make it more effective as a strategy for implementing green infrastructure on private property. They also explored opportunities to expand the programs, better incentivize disconnections, and even mandate disconnections in combined sewershed areas.

5.4 New Orleans

5.4.1 Why/ Intent of the plan

The City of New Orleans is nationally recognized city for food, music, culture and entertainment. Nevertheless, it is faced with the several threats. Rising sea levels coupled with is current development patterns, aging infrastructure system, and water management practices have contributed to poor water quality, repetitive flooding, and pollution of surrounding water bodies. On June 2, 1998, community organizations like the League of Women Voters of New Orleans and Lake Pontchartrain filed a civil action with EPA for failing to meet the standards established by the Clean Air Act and Clean Water Act.[68] The plaintiffs argued that the Sewer and Water Board of New Orleans did the following

- Discharged pollutants exceeding limitations established by NPDES permit

[68] United State of America, League of Women Voters of New Orleans, et al. v. Sewerage and Water Board of New Orleans, and the City of New Orleans, Civil Action No. 93-3212. Third Modified Consent Decree. July 2014.

- Discharged untreated sewage in the canals, ditches and conduits in the Mississippi River, Lake Pontchartrain
- Failed to report noncompliance
- Failed to properly operate treatment facilities

While the board partially denied and denied these claims, the EPA found that the city had in fact violated the Clean Air and Clean Water Act. These violations resulted in oversight of the city's management of its water system by the EPA in order to mitigate the violations. Even with the Consent Decree, it had become clear that the city's needs coupled with the additional challenge of increasing stronger storms, rising sea level and a decreasing population would require further investigation. After Hurricane Katrina, these future challenges became today's reality. As a result, other opportunities to handle stormwater in a cost-effective manner would need to be investigated. In the second Consent Decree amendment, the Sewer and Water Board of New Orleans committed to invests $500,000 per year for 5 years to explore the opportunities to implement green infrastructure into its stormwater management system.

5.4.2 Approaches to implementation

Prior to 2013, the city operated strictly with a grey infrastructure approach for resolving its water management system issues. These strategies focused on ensuring and maintaining the reliability of pump stations, implementing monitoring systems and separating sanitary and stormwater drains. While city was not prioritizing the implementation of green infrastructure, other organizations were and established successful precedents it was an effective strategy. In order to explore opportunities for green infrastructure, the city commissioned the Greater New

Orleans Urban Water plan to be completed in 2014.[69] The plan found that even with the current plan to update the drainage infrastructure system, its lack of water resiliency planning would cost the city an additional 8 billion dollars over the next 50 years in flood insurance, maintenance, decreasing property values, and potential fines. Without better management practices that allow for the city to "live with water", drastic consequences would be inevitable. This plan was commissioned by the city, and it was intended to be the recommended framework for an integrated water management system with improvement projects both grey and green over the next 50 years.

The final green infrastructure plan that was implemented by the city of New Orleans.[70] It was influenced by several documents including prior consent decrees, LPDES and MS4 permits, the Greater New Orleans Urban Water Plan, the 2010 City of New Orleans Master Plan, and the 2014 Zoning Ordinance Update. It addresses development within the private sector, social, economic, and environmental factors. As I continue this policy analysis, I will be evaluating the initiatives implemented in the green infrastructure plan from 2014 to 2017.

5.4.3 Goals and Evaluation Criteria

Unlike New York City and DC, the City of New Orleans Green Infrastructure Plan is not directly tied to or regulated by its consent order. Outside of committing financially to explore options over 5 years, the city is not required to integrate green infrastructure into its framework for water management as part of its consent order. The green infrastructure plan

[69] Waggonner & Ball Architects. "Greater New Orleans Urban Water Plan." Living With Water, Waggonner & Ball, Sept. 2013, livingwithwater.com/blog/urban_water_plan/reports/.
[70] Green Infrastructure Plan. Sewerage and Water Board of New Orleans, Apr. 2014, www2.swbno.org/documents/environmental/greeninfrastructure/GreenInfrastructurePlan.pdf.

established instead provides a framework for implementation and evaluation criteria for the private sector. The standard established in the plan was that green infrastructure created under this ordinance must manage the first one-inch stormwater to be detained, stored and infiltrated on site.

The plan indicates that the application of green infrastructure should support social, economic, and environmental goals. Socially, green infrastructure must be supported by the community. In order for green infrastructure to be a community asset and improve the neighborhood by providing aesthetic value and recreational benefits, it must be supported by the neighborhood and have maintenance procedures. Understanding how to prepare for the long-term cost implications is critical. Ensuring these projects are cost effective from their development to monitoring and maintenance phases is important for their long-term economic sustainability. Lastly, green infrastructure should be implemented on public lands and mitigate in areas of repetitive flooding in order to improve water quality through detention and filtration.

While the plan establishes criteria for proposals for green infrastructure and indicates properties where its application would be ideal, the plan does not explicitly explain how the city will implement green infrastructure. The plan alludes to green infrastructure application being the responsibility of the private sector and the public sector acting as an oversight committee. The plan acts as a guideline to how the oversight committee will evaluate proposals.

5.4.4 Analysis and Comparison

In order to analyze the green infrastructure plan, I examined the Greater New Orleans Urban Water Plan, the Green Infrastructure Plan, and the Sewer and Water Board of New

Orleans website. I cataloged the actions, programs, and the policies implemented throughout the years and the outcomes of those programs and policies. From this examination, several revelations became apparent.

Research Driven Process

The Board's framework is based on existing city's plans and efforts of existing government bodies in the city. Rather than establishing tests for feasibility, the city was able to base its framework around the success and failures of other cities' plans as well as existing research from academia. For example, the city's decision to require operation and maintenance agreements points to existing precedent. The application of a matrix correlating successful application based on factors cities research derived from the *Green Values Stormwater Toolbox Calculator* that predicts the performance of particular assets.[71] Using a matrix narrows the options for individuals to choose from while making the best and most informed decision (Figure 8).

[71] Nordman, Erik E., Isely, Elaine, Isely, Paul, & Denning, Rod. (2018). Benefit-cost analysis of stormwater green infrastructure practices for Grand Rapids, Michigan, USA. Journal of Cleaner Production, 200, 501-510.

	GI BMP →	Rain garden	Vegetated Bio swale	Green Space	Tree Planting	Green roof	Permeable pavement	Rain Barrels	Downspout Disconnection
Factors Impacting BMP Viability[i]:		[photo]							
Soil type/ Site permeability	P[ii] (positive)	High[iii]	High	High	Moderate	Low/NA	Moderate	Low	High
Groundwater level	n/m/u[iv]	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate
Size of site	p	High	Moderate	High	Moderate	Moderate	High	Low	Moderate
BMP Catchment Area	p	High	High	High	Moderate	Moderate	High	Low	Low
Flood prone Site Location	p	High	High	High	Low	Low	High	High	High
BMP Maintenance	p	High	High	Moderate	Low	High	High	Moderate	Low
Community Input/Buy-in	p	High	High	Moderate	Moderate	Low	Moderate	Moderate	High
Component Community Improvement Effort	p	Moderate	Moderate	High	Moderate	Low	High	Moderate	Moderate
Elevation	n/m/u	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Moderate
Subsidence	n/m/u	Moderate	Moderate	Moderate	Moderate	Low	High	Low	Low

Figure 8: A matrix of appropriate green infrastructure based of identified factors

Potential Feasibility Issues

As of 2019, the city has only implemented 10 green infrastructure projects, but those projects were development by the *New Orleans Redevelopment Authority* not the *Sewer and Water Board of New Orleans*. There are nine other projects that are currently under construction and over 100 projects proposed (Figure 9). While the projects have been dispersed across the city, they are not integrated into the infrastructure plan or the master plan for the city. Instead, developers are allowed to pick and choose locations and methods as long as they meet the criteria established by the city. These projects are also supported by federal funding, that is available until 2019. When the funding and financial obligation expires, the question is will the private sector continue to propose green infrastructure projects? Basing project application based on opportunities rather that a strategic long-term plan makes the application of green infrastructure less effective as an infrastructure and more of a demonstration project.

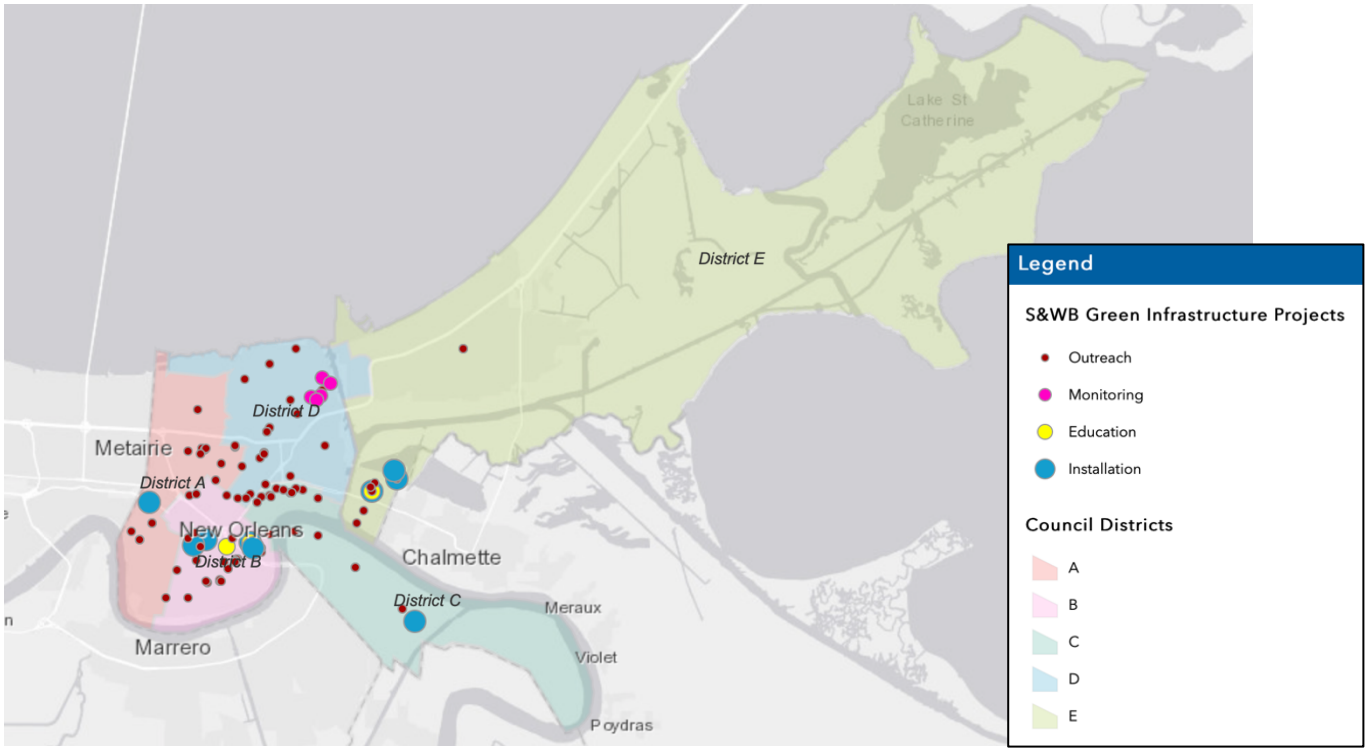

Figure 9: A map of the existing green infrastructure projects in New Orleans

The plan also doesn't address how to incentivize the retrofitting of properties in order to contribute to the city's sustainability and resilience goals. With even the cheapest option of green infrastructure, like rain barrels, the city can make considerable efforts to extend the time it takes to accumulate 1" inch of rainfall (Figure 10). This type of solution would be cost effective and space effective for both residents and the city. By basing green infrastructure projects implemented by predominantly large projects, you are missing opportunities to capture the population of early adopters that may or may not be financially able to implement larger project types.

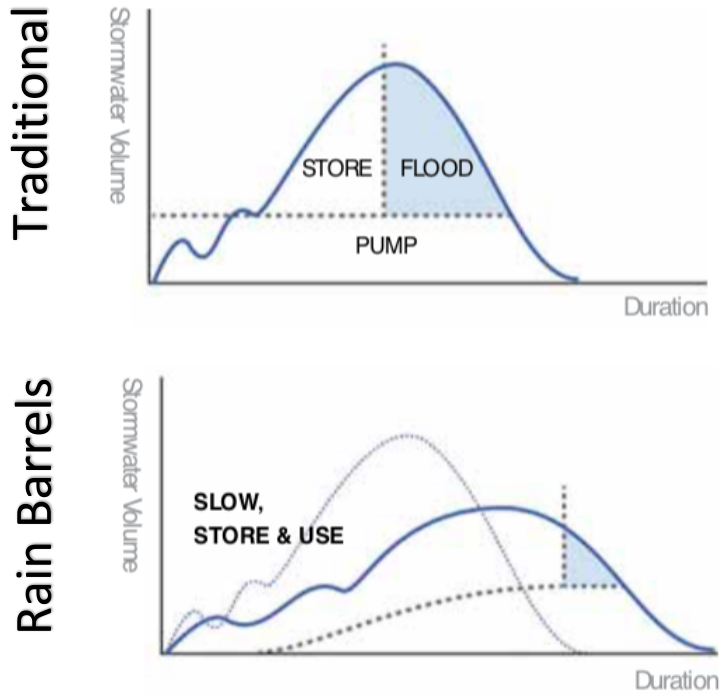

Figure 10: Charts comparing how even rain barrels can be more effective than traditional water infrastructure systems

Lack of Enforcement

Continuing to implement green infrastructure with limited funding sources and no obligation from the federal government is not likely to occur. The third revision of New Orleans' Consent Decree required the city to financially support the green infrastructure until 2019.

Now, it is up to the administration of the New Orleans Redevelopment Authority to continue the operations of its land stewardship programs which houses green infrastructure projects. As long as the city is meeting the timelines of the Consent Decree, it is not obligated to continue the green infrastructure programs outside of the regulations in the code. Unless the city was willing to invest in green infrastructure as an alternative to items within the Consent Decree and go to the EPA to make that revision, the lowlihood of the continuance of the program at current pace is minimal.

While the Greater New Orleans Urban Water plan displayed more detailed and site focus projects than the Green Infrastructure Plan, the amount of investment required for executing it is astronomical. In order to execute the Greater New Orleans Urban Water Plan, the city would need to invest 63 billion dollars over the next 50 years. This would require new taxes, increase cost to water services, public support and sustainable grant funding to even be viable. With no strategic plan explicitly adopted for the next 50 years or an existing governing body working to execute the plan, it would take additional time to even realize the plan.

6.0 Analysis and Comparison of all the Green Infrastructure Plans

Based on the analysis of these three green infrastructure plans, I was able to compare and contrast the plans based on factors informed by research following the framework of the triple bottom line. I ranked the three green infrastructure plans were ranked by factors from one to five and then summed into categories- social, economic, and environmental (Figures 11 and 12). Of these factors, a “research driven process” and “innovation” were scored the highest. Regional planning efforts, enforcement capability and sustainable funding sources scored the lowest. The factors were combined into categories representing economic, social, and

environmental factors. Based on these factors, I determined that economic factors were prioritized more than social and environmental factors. After comparing the three infrastructure plans, I determined that the Washington D.C. plan best addressed the social, economic, and environmental factors compared to New Orleans and New York City. Of the three plans, New Orleans scored lowest for its prioritization of social, economic and environmental factors.

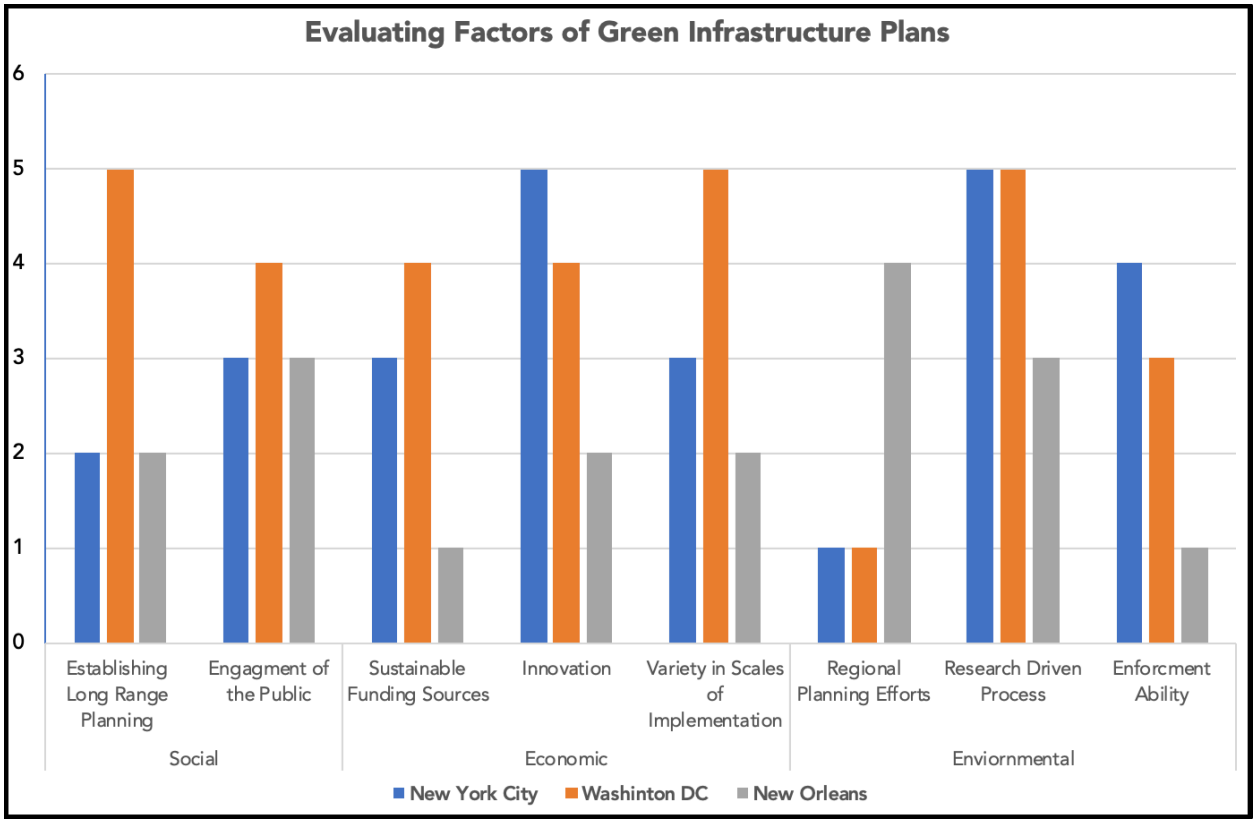

Figure 11: Chart of the Factors used to evaluate the Green Infrastructure Plans

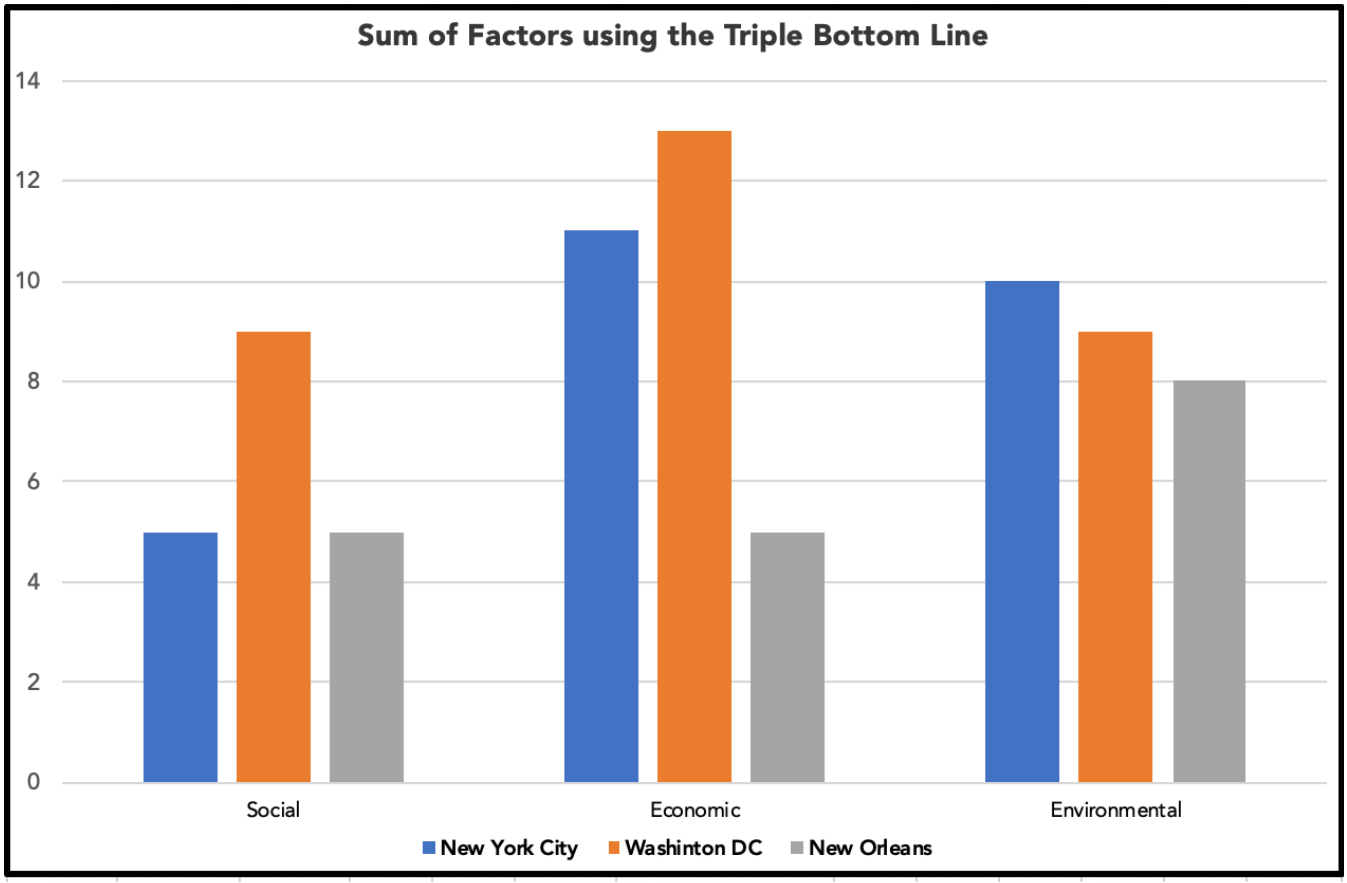

Figure 12: Chart of the Factors summed based on the principles of Social, Economic, and Environmental

7.0 Recommendations for the Atlanta Context based on levels of Investment

Based on precedent cases and previous case studies, it is clear that green infrastructure plans are a reactive response to negative environmental effects and the financial cost of building additional traditional grey infrastructure. While green infrastructure is a federally supported strategy, cities have little incentive to implement a plan that adequately addresses all the factors that contribute to stormwater management. Instead, cities pursue a checklist approach that optimizes on the opportunity for economic benefit, mitigates current environmental hazards, and provides a social benefit. In order to be more forward thinking in our approach and adequately prepare for future challenges, we need to change our processes.

Planning for the present and the future indicates that we need to understand the "needs" in order to lessen the burden of costs, capitalize on opportunities, and provide overall benefit.

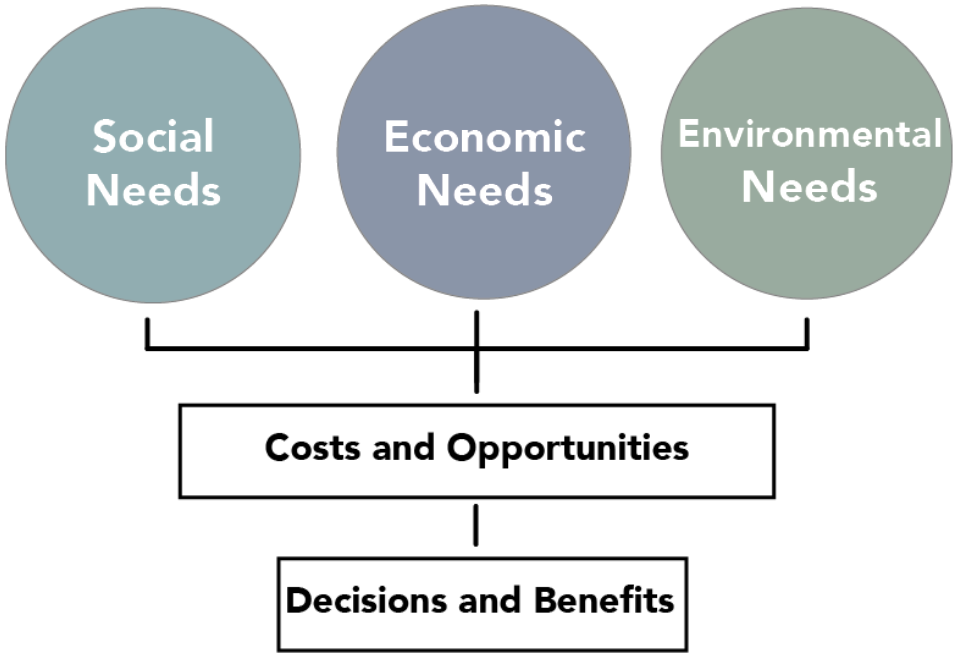

Figure 13: The Hazards and Needs Assessment is an alternative framework proposed for looking decision making

In order to address the needs, we can use GIS to spatially correlate factors based on the water basin area. By using geographical boundaries like the watershed, we can better address environmental factors. This framework would be informed by a variety of factors that could influence regional planning, design, and phasing. This framework would be a *Hazards and Needs Assessment* based on water basin area (Figure 13). Similar to the triple bottom line framework, we will continue to base this assessment on the principles of social, economic, and environmental in order to be comprehensive in our approach.

7.1 History of Atlanta

Like the three other cities, Atlanta has a history of issues with the management of its wastewater system. Atlanta previously had a CSS that collected stormwater and wastewater in the same pipes. When heavy rains bombarded the system with additional volume, overflows were let out into the Chattahoochee River, the South River and tributary creeks. This system would be deemed environmentally detrimental today, but in the past it was considered appropriate and efficient. With an increasing population and an increasing amount of impervious surface, the base line amount of water in the CSS increased. This resulted in an increasing number of CSO events and greater pollution to the Chattahoochee River, the South River and tributary creeks. In 1998, the Upper Chattahoochee Riverkeeper Fund, the Chattahoochee River Inc. and W. Robert Hancock Jr. filed a complaint with the EPA alleging that the City of Atlanta was in violation of the Clean Water Act and had violated the terms of its NPDES permits for several of its CSO Control Facilities.[72]

This complaint resulted in the EPA requiring monitoring and reporting of water quality, the beginning of remedial measures, development of a CSO management plan, and the beginning of sewer separation. In 1999, an additional complaint was filed as the City of Atlanta had violated the Georgia Water Quality Control Act by not entering into interjurisdictional agreements and depositing sewage into State of Georgia waters.[73] Since this time, the City of Atlanta has taken immense strides to meet the requirements of the Consent Decree. The processes outlined focused on monitoring and modernizing the CSS with grey infrastructure

[72] Upper Chattahoochee River Keeper, et al. v. The City of Atlanta, Consolidated Civil Action No. 1.95-CV-2550-TWT. Consent Decree. May 1998.
[73] United States of America and The State of Georgia. v. The City of Atlanta, Consolidated Civil Action No. 1.95-CV-2550-TWT. First Amended Consent Decree. June 1999.

improvements. These improvements have cost the city billions of dollars which contributes to why the City of Atlanta's water bills grew to one of the most expensive in the country. It is important to note that the main difference between the City of Atlanta and the previous case study cities is that Atlanta's Consent Decree predates the EPA memo supporting green infrastructure. While the city has taken the opportunity in recent years to explore the application of green infrastructure with the use in parks and allowing its use on private property, the City has no overall established plan of how to best integrate green infrastructure into the citywide management of stormwater.

The city's lack of an established plan provides it the opportunity to create a plan that is cognizant of the social, economic, and environmental factors that are at stake. Using the framework of the *Hazards and Needs Assessment* and GIS, we can assess the watersheds within the City of Atlanta to help inform a future plan and decision making. The following sections are a test of the *Hazards and Needs Assessment* using proxy factors based on the principles of social, economic, and environmental stewardship. Research does highlight various characteristics that could be assessed, but the factors then could be considered are spatially located and are able to be assessed at the scale of the watershed. Future studies should look for opportunities to integrate additional factors that can be spatially located like the distribution of settlement patterns.

7.2 Methods for Documenting Social Factors

Assessment of social factors requires analyzing access to parks and mobility services. To test a method for analyzing green infrasturture model, I have chosen these factors for their readily available data. Factors like proximity to parks and alternative mobility services and age

distribution would be documented in this category (Figure 14 and 15). Proximity to parks and mobility services are based on a 10-minute walk or ½ mile distance. This number is derived from literature that suggest that a 20-minute walk is reasonable to walk from transit. But people are more willing to walk 10 minutes[74]. While understanding the composition of a community is critical to the planning process, there is very little research to identify the support of projects by age, race, and ethnicity. Also, the scale of available spatial information on age is a limitation which makes it ineffective for the purpose of this analysis. However, the design of green infrastructure that incorporates park-like elements like playgrounds and sport fields should be taken into account of these factors in the planning process. Planning and adding elements to the park that are desired by the existing community is critical for building consensus and support around a project. The consideration of factors like unemployment percentages, population change, and median household income are not best recognized at the watershed level. While these elements are important, I do not recommend the averaging these factors. It is recommended that if efforts are made to consider factors, the scale should neither overestimated or underestimated the facts. In the case of social factors, it would be appropriate to subdivide the watersheds based on similar neighborhood characteristics to provide the best representation. I recommend that future in the future as the underlying primacy of urban form is given more attention, perhaps data sets should be arranged and subdivided by the watershed area rather than a census tracts and other politically defined boundaries.

[74] Burke, Matthew and Brown, AL. Distances People Walk for Transport [online]. Road & Transport Research: A Journal of Australian and New Zealand Research and Practice, Vol. 16, No. 3, Sept 2007: 16-29.

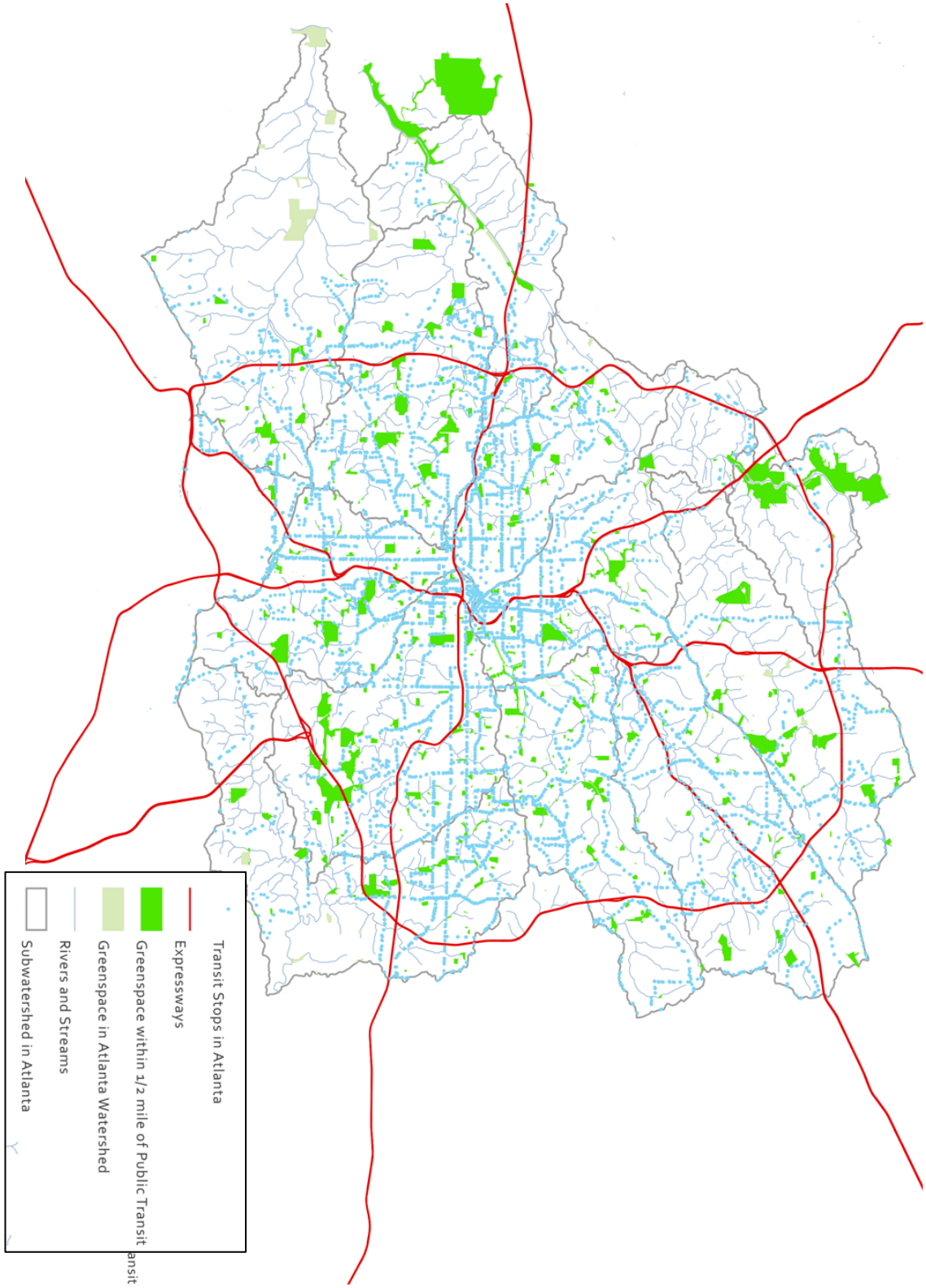

Figure 14: A maps of the parks distributed in the watershed

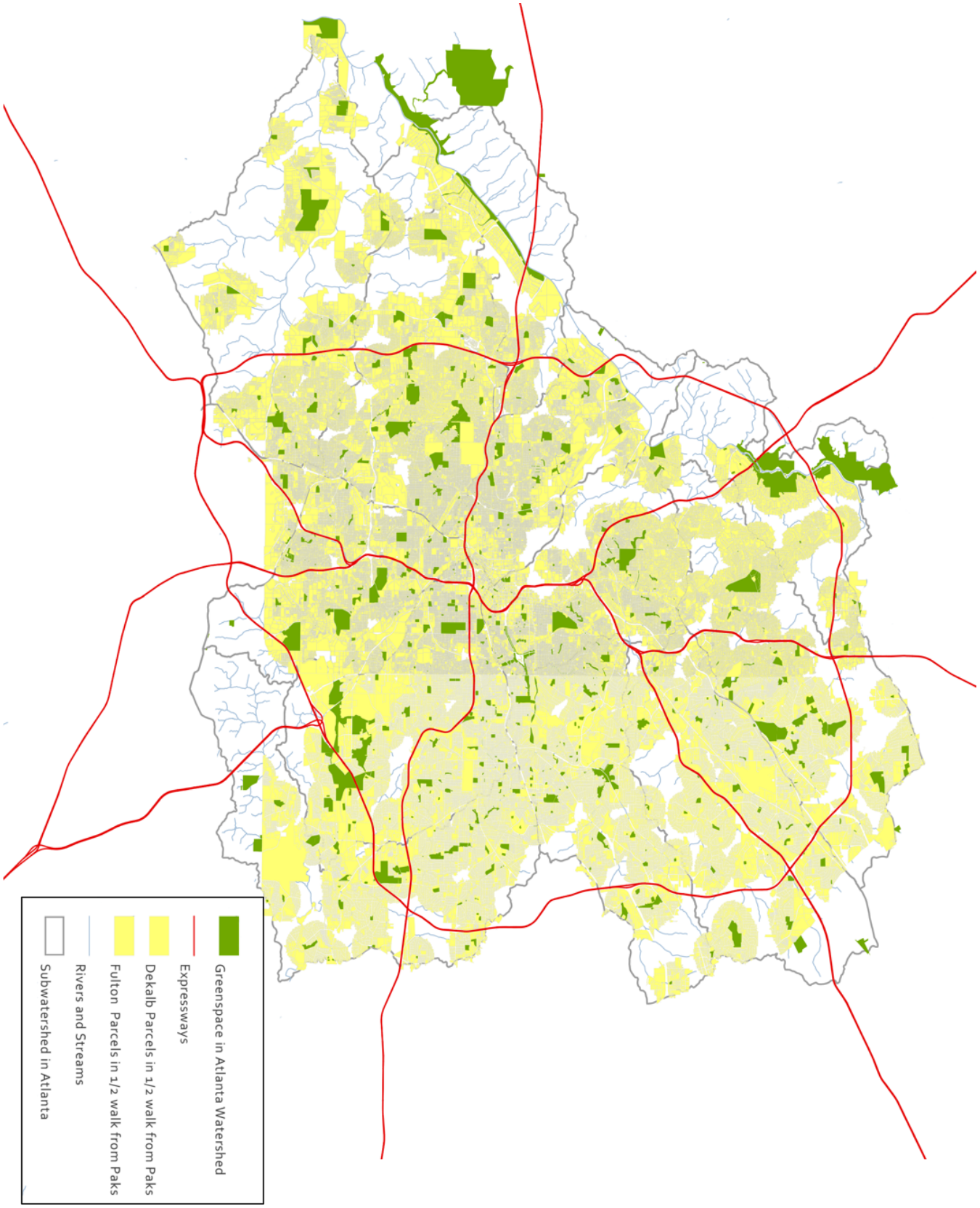

Figure 15: A maps of areas accessible to parks within a 10-minute walk

Using the factors identified, I determined that “Long Island Creek-Chattahoochee River”, “Wilson Creek-Chattahoochee River”, and “Camp Creek” had the least access to parks and public mobility services. This provides insight to where investment that could be made that would fill in gaps of access in addition to highlighting the need to provide more public transit in order to serve those that lack the ability to drive to locations.

7.3 Methods for Documenting Economic Factors

Assessment of economic factors would look at economic mobility and economic status. Factors such as land use and the existence of a special public interest district and community improvement districts would provide insight to how the community is organized and represented in decision making processes (Figure 16, 17 and 18). While community’s unemployment characteristics were considered, I determined that consolidating these factors led to a generalization that overrepresented and underrepresented communities. Even though this information is spatially located, aggregating this information on the watershed level is challenging. Additionally, point data, which would be the most ideal, is likely protected and needs authorization to have access to. I recommended that these characteristics be noted and utilized for economic development opportunities on a neighborhood by neighborhood basis.

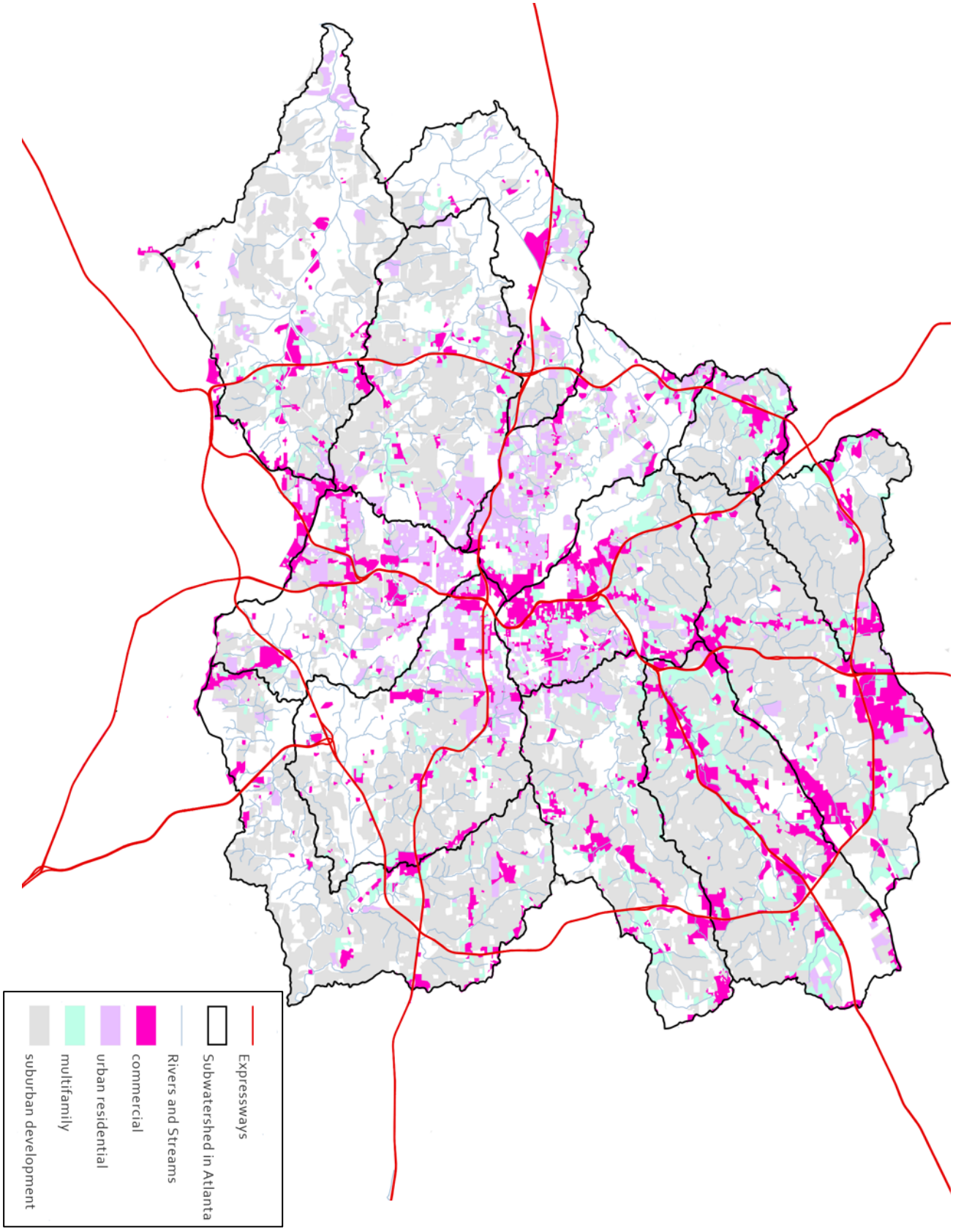

Figure 16: A maps of land use distribution across the watershed

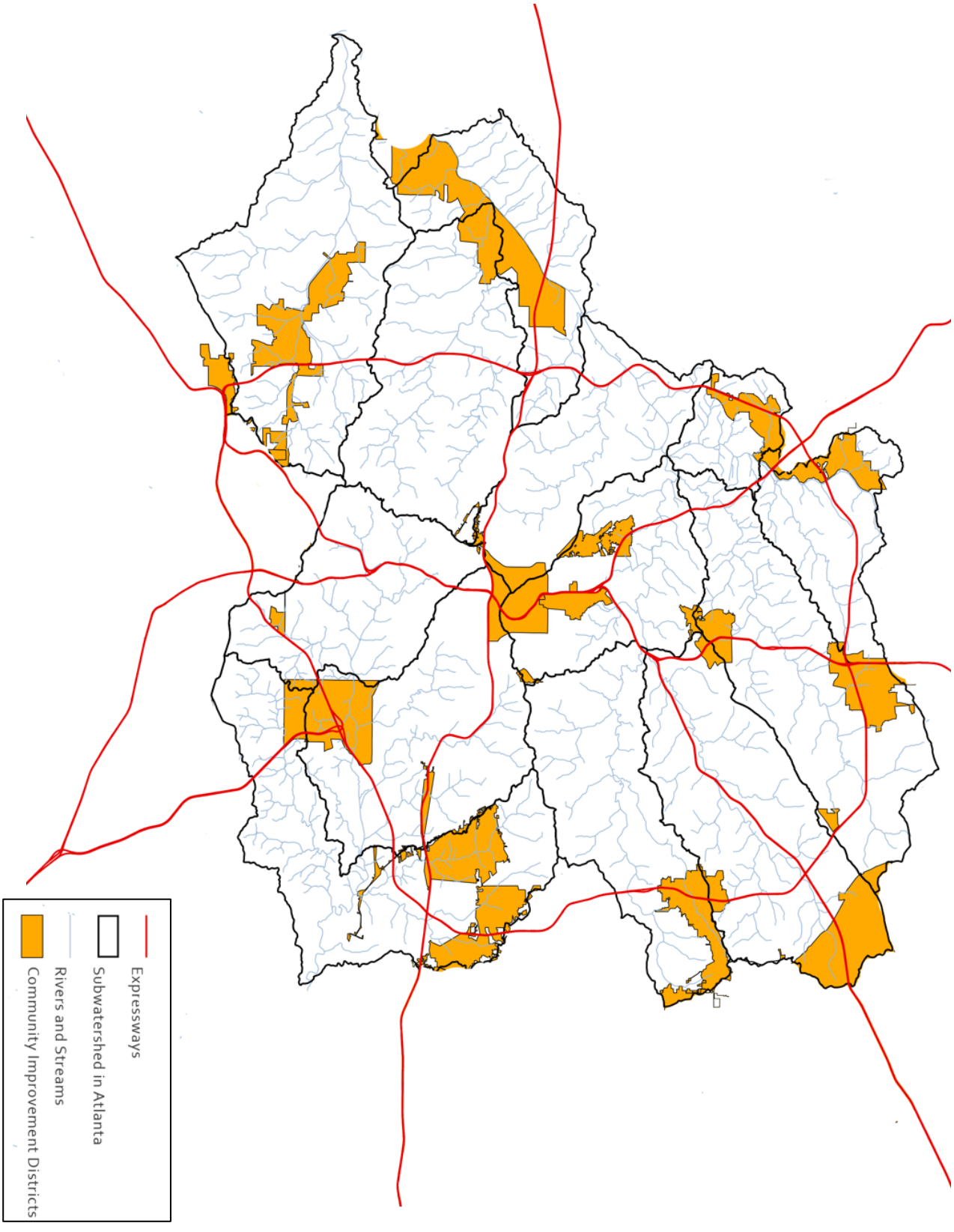

Figure 17: A map of the location of Community Improvement Districts in the Watershed

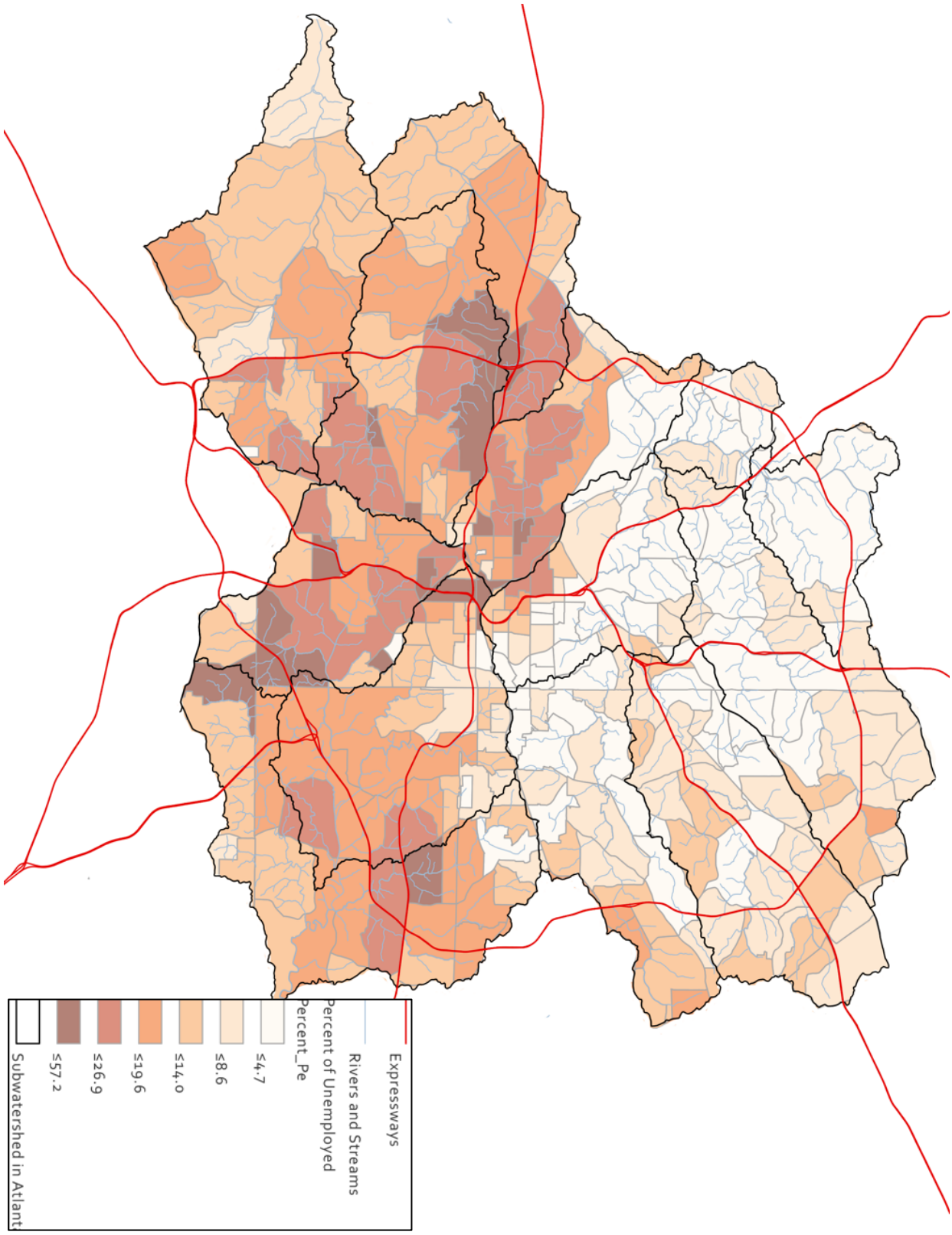

Figure 18: A map of unemployment percentages in the watershed

Using the factors identified, I determined that “Sugar Creek-South River”, “Shoal Creek-South River”, and “Camp Creek” had the least economic mobility and organization. This analysis provides insight into how well politically represented communities are. Communities within a watershed that ranks high are likely to be vocal from the planning process to the opening of the project. If these communities strongly oppose a project, it is important to note that they are likely to be highly organized and supported financially as opposed to communities ranked lower. This analysis also highlights watersheds that are likely to need additional support measures to prevent gentrification and displacement if a large infrastructure project is proposed. Lastly, the presence on a Community Districts highlights the existence of organized businesses and property owners. Cities can frame relationships with these organizations to better understand the needs and issues of the community. These organizations could also be partnered with fundraising for a project, coordinated community-based employment programs, and build community support around the project.

7.4 Methods for Documenting Environmental Factors

Assessment of the existing environmental conditions would recognize the community’s exposure to natural water bodies within the watershed. Factors like direct property exposure to water bodies, exposure to 100-year flood, and parks exposure to water bodies would be able to help identify threats and opportunities to capitalize on existing infrastructure vs the need to increase it (Figure 19). With the effects of climate change, the boundaries of FEMA’s 100- year floodplains are becoming less reliable. Cities should plan for today’s issues and be cognizant of the futures. With this in mind, I buffered the FEMA’s 100-year flood boundary by an additional

10 feet to identify properties that are exposed to the 100- year flood as well as properties that may be exposed in the near future. With further exploration of properties in the watershed area, it became apparent that there was no clear identification system notating parcels that were developed vs undeveloped in both Fulton County and Dekalb County. The city's data also lacks information on the ratio of impervious and pervious surfaces. Identification of developments that are not contributing to the best management practices, as it applies to the management of water, would allow the city to design policies to incentivize conversion of properties to be better performing in the management of stormwater. Lastly, the volume of water expelled and managed by each watershed is not public information. Identifying these qualities could be utilized as a normalization factor for the entire analysis or solely the environmental section to recognize the magnitude of the environmental problem. It is recommended that these variables be further considered with other explorations of this framework.

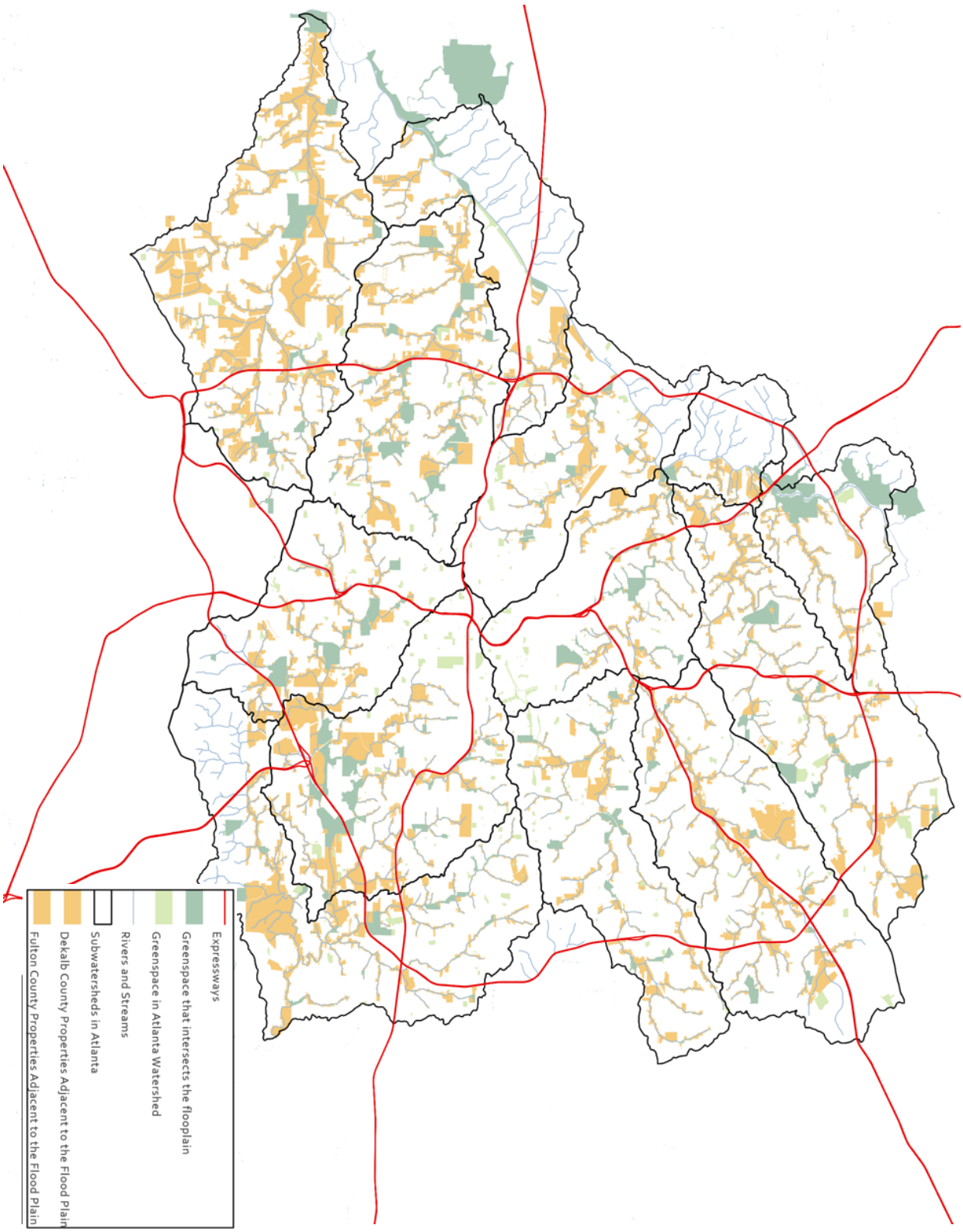

Figure 19: A map of the greenspaces and the 100-year flood plain in the watershed

Using the factors identified, I determined that “Camp Bert Adams Lake-Chattahoochee River” and “Long Island Creek-Chattahoochee River” had the greatest number of properties exposed to the flood plain and the least number of parks intersecting the flood plain. This analysis provides insight to magnitude of the threat within the watershed based on the quantity or properties exposed.

Summarizing these factors, it becomes evident that “Sugar Creek-South River”, “Camp Creek”, and “Camp Bert Adams Lake-Chattahoochee River” have the greatest need based on the *Hazards and Needs Assessment*. This assessment tries integrate proxy factors that may provide indications that acknowledge the needs of the community, forecast environmental threats, and highlights leverageable opportunities based on the economic productivity of the community. With further research around gentrification and displacement, additional factors can be added to better inform the assessment. It is important to emphasize that this assessment is not a plan, but merely a tool to inform the planning and decision-making process. Therefore, it must be utilized at all stages of decision making if we are to be more sensitive, thoughtful, and forward thinking in our approach to spending around public infrastructure projects.

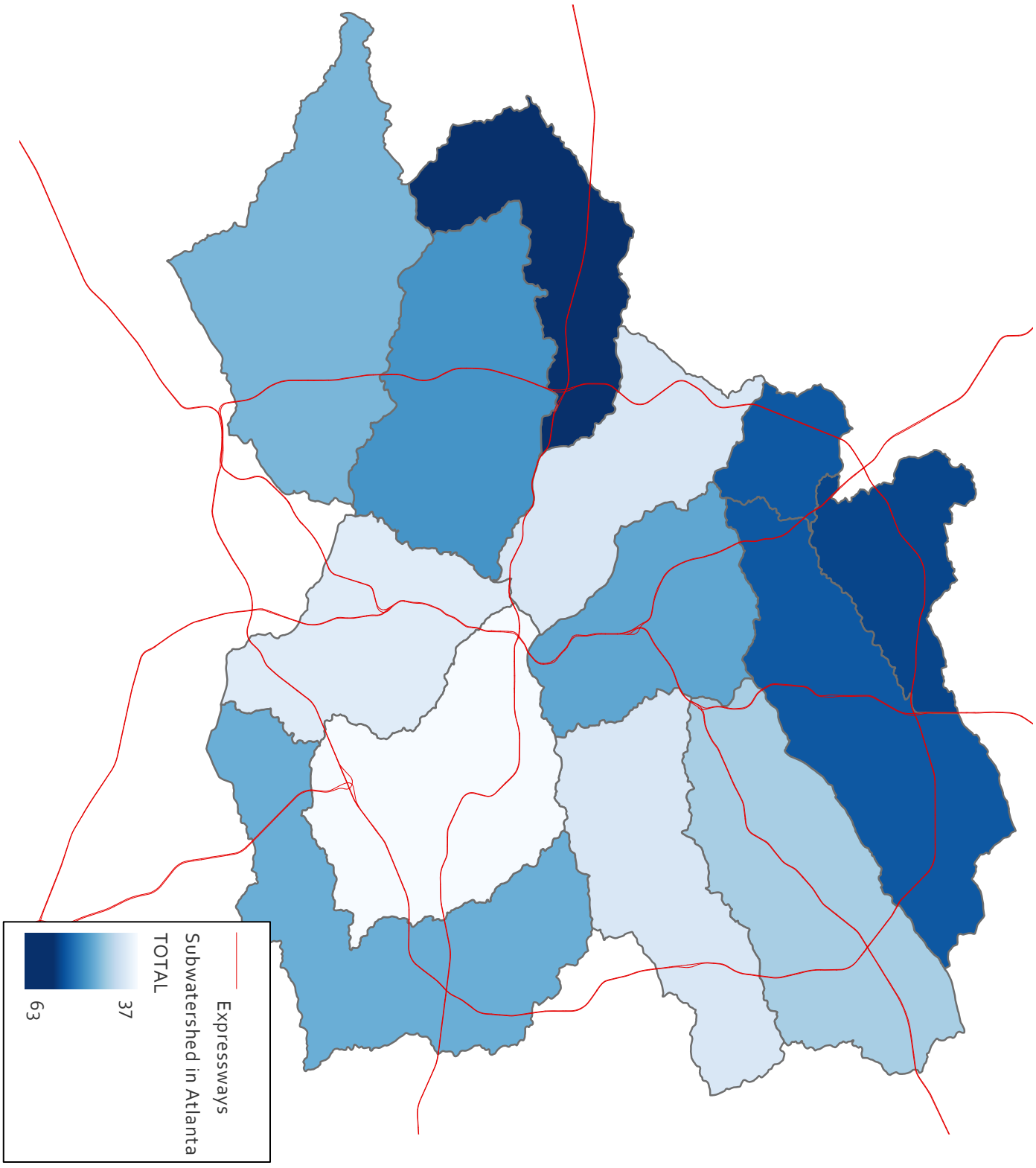

Figure 20: A map of all the factors summarized and ranked by watershed

8.0 Conclusions

The problem of stormwater and water management is not a toy problem or a new one. It is a problem that will continue to be heightened in visibility and discussion amongst local government and private citizens. The management of water is a requirement for cities today and the resilience of their future. With emerging research, planning, and design efforts, cities have a toolbox of strategies to choose from as opposed to the short list they had in the past. Nevertheless, with options comes a greater opportunity to succeed and fail- socially, economically, and environmentally. In the past, local government has made decisions based on a framework that doesn't explicitly describe how to analyze the facts and incorporate it into the decision making, but instead prioritizes outcomes. Acknowledging the gaps in the framework and implementing processes to make better decisions is critical for implementing smart and practical investment. Public investment should solve critical local issues rather than help accelerate the intensity of national ones for example displacement and gentrification.

This analysis, while imperfect, highlights the best and worst of our government systems. Nevertheless, we have opportunities to improve it. With the framework proposed, we have the opportunity to better assess challenges cities face to better to inform best decision making while continuing to build on the successes of predecessors. Previously, the EPA began to support alternative strategies to resolve our problem with water. This analysis can support the beginning of the discussion on the next steps forward. While the government cannot force cities to adopt policies unless it has the political will, its endorsement of best management practices acts as a catalyst for change in cities, industries, and in local communities.

Whether this framework is tied to legal constraints or simply applied on the local level, it can be a standard model for applying green infrastructure plans with humanity involved and in a way that meets human needs and aspirations for a better life.

Glossary

Acronyms:

- *EPA* - Environmental Protection Agency
- *CSS* - Combined Sewer System
- *CSO* - Combined Sewer Overflow
- *NYCDEP* - New York City Department of Environmental Protection
- *NYSDEC* - New York State Department of Environmental Conservation
- *DC Water* - District of Columbia Water and Sewer Authority
- *GIS* - Geographic Information System
- *LPDES* - Louisiana Pollutant Discharge Elimination System
- *NPDEA* - National Pollutant Discharge Elimination System
- *MS4* - Municipal Separate Storm Sewer System

Definitions:

- *Grey infrastructure*- A traditional engineered system by people to manage stormwater that includes pipes, pumps, ditches, and detention ponds.
- *Consent Order* - A voluntary agreement worked out between two or more parties to a dispute. It generally has the same effect as a court order and can be enforced by the court if anyone does not comply with the orders.

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